



**Scientific, Technical and Economic
Committee for Fisheries (STECF)**

**Report of the Sub Group on Management
Objectives and Strategies (SGMOS 10-06).
Part b) Impact assessment of North Sea
plaice and sole multi-annual plan**

PREPARED IN DRAFT BY THE

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**SCIENTIFIC, TECHNICAL AND ECONOMIC COMMITTEE FOR FISHERIES
(STECF)**

**STECF COMMENTS ON THE REPORT OF THE SUB GROUP ON MANAGEMENT OBJECTIVES
AND STRATEGIES (SGMOS 10-06). PART B) IMPACT ASSESSMENT OF NORTH SEA PLAICE
AND SOLE MULTI-ANNUAL PLAN**

**STECF OPINION EXPRESSED DURING THE PLENARY MEETING (PLEN-10-03)
HELD IN BRUSSELS, 8-12 NOVEMBER 2010**

1. INTRODUCTION

STECF is requested to review the reports of the **SGMOS-10-06** Working Group of October 18 – 22, 2010 (Vigo) meeting, evaluate the findings and make any appropriate comments and recommendations.

When reviewing the SG-MOS 10-06b report, the STECF was asked to highlight limits faced when evaluating or assessing management options in terms of economic and social impacts. STECF will be also requested to suggest paths to reduce these limits, either by indicating possible assumptions which would be followed to make fisheries, métiers and fleets matching better or by highlighting possible modifications to the list and to the level of aggregation of economic parameters listed in the DCF.

2. TERMS OF REFERENCE

The STECF (SG-MOS 10-06) is requested to

A) Evaluate the following plans:

1. Multi-annual plan for hake and Nephrops in ICES sub areas VIIIc and IXa
2. Multi-annual plan for cod in the Baltic

Following and taking into account *inter alia* the STECF framework specified in Annex C of SG-MOS 10-06a and WDs prepared by participants prior to the meeting. Separate reports should be prepared for each plan.

B) Provide an Impact Assessment of the following plans:

3. Multi-annual plan for sole in the Western Channel
4. Sole and plaice in the North Sea

by taking into account *inter alia*, the external report prepared by MRAG on assessing the impact for the revision multiannual plan for sole and plaice, WDs on sole and plaice prepared by IMARES, LEI, and WD prepared by CEFAS and Seafish on WC sole. The report should follow the STECF framework specified in Annex B of SG-MOS 10-06a. Separate reports should be prepared for each plan.

3. STECF COMMENTS AND CONCLUSIONS

Approach to the work

In line with the STECF process, described in the STECF-SGMOS 09-02 and STECF-SGMOS 10-01 WGs, STECF set up a scoping meeting SG-MOS 10-06a which was held in Copenhagen in June 2010. This group involved Commission staff, Observers and STECF experts. The scoping meeting produced a report (STECF-SGMOS 10-06a) which specified a series of work activities to be carried out before the October meeting. Following this Working Documents were prepared by participants for the main meeting which was held 18-22 October 2010 in Vigo, Spain. At this meeting there were 19 experts (6 economists and 13 biologists), Five Commission staff attended part time (including two from CFCA) and eight observers nominated by Baltic, NS, NWW and SWW RACs, Member States and ICES. The study group was open to observers throughout and their participation was regarded by the group as a particularly important part of this work. The working procedures were organised to facilitate observer participation by scheduling the presentation and discussion of topics on specific days to allow part time attendance if required. STECF is grateful for the input from observers.

Reports

In total five separate reports are prepared by STECF-SGMOS 10-06 WGs, the first, scoping meeting report STECF-SGMOS 10-06a was dealt with by the STECF summer plenary. The remaining four reports are dealt with here:-

STECF-SGMOS 10-06b Report of the Impact Assessments for North Sea plaice and sole multiannual management.

STECF-SGMOS 10-06c Report of the Impact Assessments for Western Channel sole multiannual management.

STECF-SGMOS 10-06d. Report of the Evaluations of Southern hake and Nephrops Multi-annual plan

STECF-SG MOS 10-06e. Report of the Evaluations of Baltic cod Multi-annual plan

STECF provides below general comments and conclusions on this Impact Assessment the comments aspect of the ToR are included in the other reports (SGMOS 10-06c-e).

STECF Comments

Modelling: STECF considers the biological modelling was appropriate, it was developed to include a range of different stock dynamics within the base case model incorporating uncertainty in stock recruitment function, measurement error and variability in the fishery. Several alternatives were tested and under the scenarios investigated the long term trends in stock development and TAC did not show any notable differences that would invalidate the use of the chosen base case scenario. A range of management scenarios examined the likely impacts of varying aspects of the multi-annual plan on the stocks and the fishery. These included different candidate F targets for each stock, increasing the allowable annual TAC change, and increasing the annual F reduction percentage.

Long term Objectives: The simulations show that given the probability of $SSB < Blim$ for both North Sea plaice and sole the current plan can be accepted as precautionary in the long term and will reach management plan targets for both plaice and sole. There are no indications that the F target for sole should be amended from $F = 0.2$. There are indications that a target of $F = 0.23$ for plaice would be a more appropriate F target for MSY.

Robustness to collapse: The simulations show that the plan for plaice appears robust to stock collapse through recruitment failure, the same is not the case for sole (though the likelihood of this happening is thought to be low). However, if this was to happen, some additional action is required. Such action is implied in the management plan but is not explicitly described. It is considered that the best trigger for remedial action should be a value for mean recent recruitment, though the most suitable period and value has not yet been determined.

Compatibility of sole and plaice targets: In the simulations the link between plaice and sole fishery is limited. However, scenarios considering linked fishing effort for the two stocks show that the plan is robust to a range of mixed fishery scenarios. The long term matching of the two F targets will always be a potential problem. Given the historic ratio of F_{sole} / F_{plaice} the proposed F_{msy} target for plaice of $F = 0.23$ is more in line with the $F = 0.2$ target for sole than the current plaice target of $F = 0.3$.

As a general strategy for this mixed fishery it is thought to be sensible to keep plaice SSB high in line with the MSY objective because if fishing opportunities for plaice become limiting, catches of sole may have to be reduced to protect plaice. In contrast if sole becomes limiting it would still be possible to catch plaice outside the areas where sole is caught.

Interannual constraint on change in TAC. The current 15% constraint is considered acceptable from a biological perspective. If there was a desire to change this limit an increase of up to 25% would make the exploitation safer from a biological perspective. Increasing the limit about 25% is not helpful, increasing variability in TAC for no benefit.

Economic considerations suggest the fleets are currently generally in profit and the prognosis is good for most fleets. Allowing the shifting of effort between mixed plaice and sole fishery and towards a plaice only fishery would be economically beneficial, allowing more plaice to be caught when fishing for sole is limiting. However, such an arrangement might necessitate area regulation and must be compatible with cod recovery requirements.

ANNEX 1 REPORT OF THE SUB GROUP ON MANAGEMENT OBJECTIVES AND STRATEGIES (SGMOS 10-06). PART B) IMPACT ASSESSMENT OF NORTH SEA PLAICE AND SOLE MULTI-ANNUAL PLAN

SUMMARY

THE SGMOS 10-06 met Copenhagen in June 2010 and produces a scoping plan for the Impact Assessment of the NS plaice and sole plan. The group met again in Vigo between 18-22 October 2010 and prepared this report for the November 2010 plenary of STECF. Based on the evaluation carried out the group came to the following conclusions:-

Biological modelling was developed to include a range of different stock dynamics within the base case model. Several alternatives were tested and under the scenarios investigated the long term trends in stock development and TAC did not show any notable differences that would invalidate the use of the base case scenario. A range of management scenarios examined the likely impacts of varying aspects of the multi-annual plan on the stocks and the fishery. These included different candidate F targets for each stock, increasing the allowable annual TAC change, and increasing the annual F reduction percentage.

The current plan can be accepted as precautionary and will reach MSY targets for both plaice and sole. There are no indications that the target for sole should be amended from $F = 0.2$. There are indications that a target of $F = 0.23$ for plaice would be a more appropriate F target for MSY. This might also be more in line with F target for sole.

While the plan for plaice appears robust to stock collapse through recruitment failure, the same is not the case for sole unless some additional action is taken. Such action is implied in the management plan but is not explicitly described. It is considered that the best trigger for remedial action should be a value for mean recent recruitment, though the most suitable period and value has not yet been determined.

In the simulations the link between plaice and sole fishery in evaluations is limited. However, scenarios considering linked effort for the two stocks show that the plan is robust to a range of mixed fishery scenarios. The long term matching of these targets will always be a potential problem though the change of F target for plaice may help. As a general strategy it is thought to be sensible to keep plaice SSB high because if plaice become limiting catches of sole may have to be reduced to protect plaice. In contrast it is still possible to catch plaice outside the areas where sole is caught this if sole becomes limiting there is scope to continue to catch plaice.

There is no specific need to alter the interannual limit to TAC change. An annual TAC change of greater than 25% has limited impact and thought to be too great. Increases up to 25% make the exploitation safer from a biological perspective.

Economic considerations suggest the fleets are generally in profit and the prognosis is good for most fleets. allowing switching of effort between mixed and plaice only fleet activity would be beneficial but would necessitate area regulation and must be compatible with cod recovery requirements.

**SCIENTIFIC, TECHNICAL AND ECONOMIC COMMITTEE FOR FISHERIES
(STECF)**

**MULTI-ANNUAL PLAN EVALUATIONS AND IMPACT ASSESSMENTS B) IMPACT ASSESSMENT
OF NORTH SEA PLAICE AND SOLE MULTI-ANNUAL PLAN**

1. INTRODUCTION

This report is one of four prepared under SGMOS 10-06b, each dealing with a separate item on the ToR below. The work followed the plans from the Scoping meeting SGMOS 10-06a Copenhagen 7-11 June 2010. This report follows the structure defined by STECF which is given below in Appendix A.

2. TERMS OF REFERENCE

The STECF (SG-MOS 10-06) is requested to

A) Evaluate the following plans:

1. Multi-annual plan for hake and Nephrops in ICES sub areas VIIIc and IXa
2. Multi-annual plan for cod in the Baltic

Following and taking into account *inter alia* the STECF framework specified in Annex C of SG-MOS 10-06a and WDs prepared by participants prior to the meeting. Separate reports should be prepared for each plan.

B) Provide an Impact Assessment of the following plans:

3. Multi-annual plan for sole in the Western Channel
4. Sole and plaice in the North Sea

by taking into account *inter alia*, the external report prepared by MRAG on assessing the impact for the revision multi-annual plan for plaice and sole, WDs on plaice and sole prepared by IMARES, LEI, and WD prepared by CEFAS and Seafish on WC sole. The report should follow the STECF framework specified in Annex B of SG-MOS 10-06a. Separate reports should be prepared for each plan.

The scoping meeting is reported in SG MOS 10-06a. The Evaluations are dealt with in reports SG-MOS 10-06d, e and the Impact Assessment for WC sole in SG MOS 10-06c.

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4. PROBLEM STATEMENT

Plaice and sole have been fished together for many decades in the southern North Sea. When the long term management plan was first proposed in 2005, the fishing mortality on plaice had more than doubled since the 1950s, and the biomass had been below Bpa for several years. Similar trends had been observed for sole. A plan was implemented in 2006.

Following the evaluation of the past performance of the NS plaice and sole multi-annual plan there is a need to assess options for the future. A study is required to provide background information on the performance of a multi-annual plan for North Sea plaice and sole fisheries. The aim of this is to assess the impact of the current management plan for North Sea plaice and sole and to evaluate if any alternative strategies might deliver improved environment, economic or social outcomes.

5. OBJECTIVES OF THE PLAN

The first phase of the multi-annual plan for plaice and sole was intended to bring both stocks back to within safe biological limits (biomass greater than Bpa and fishing mortality less than Fpa). Once this had been achieved for both stocks for two consecutive years the plan would enter a second phase, geared to the long term management of the two stocks.

For two successive years, the plaice stock has been classified within safe precautionary limits and has thus met the objectives of the first phase of the plan. This is not yet the case for the sole stock, though it is likely that it will be before any revised plan enters into force.

The objectives of plan can be categorised into biological, environmental and economic. The principle biological objectives should be to fish both stocks at mortality rates consistent with Fmsy by 2015, and to maintain those rates in subsequent years with a low risk that the stocks will move outside safe biological limits in the medium term. A secondary biological objective might be to reduce discards.

The environmental objectives should be that the plan is consistent with the achievement of good environmental status by 2020.

The economic objectives should be to provide stability by constraining inter-annual variations in TAC. Another economic objective might be to move towards maximum economic yield, though this would require a clear definition of the group or groups for which the economic benefits are maximised.

6. CHOICE OF TACTICAL METHODS

6.1. Main tactical methods

Both TAC and effort controls are used for this management plan.

6.2. Potential for spatial management

SGMOS 09-02 reported that TACs had been the main limiting factor in impact of the fishery. Therefore simulations have mostly been carried with TAC constraint. Some combined TAC and Effort regimes have been tested. The current rule requires effort reduction in line with the more restrictive advice for the two species. However, to deal with the imbalance in effort there is a potential for spatial management to balance the mixed fishery TACs under some circumstances. Recently the sole targets have been more limiting than the plaice targets. However, there are more northerly areas of the North Sea where concentrations of plaice are much higher than sole. North of 56°N (Council Reg. 2056/2001) the mandatory 120mm mesh nets will catch plaice with negligible sole catches. A fishery to take plaice independently of sole is therefore possible in these more northerly areas of the North Sea. If there is surplus effort available in addition to that required to take the sole TAC, it would be possible to redeploy that effort within a spatial management regime (subject to any restraint resulting from the NS cod plan).

This type of approach would give a mechanism for balancing unfished plaice quota in the absence of sole quota but not the reverse. However, it would require spatial effort regulation, restricting the transfer of existing and potential additional effort from the more northerly (plaice fishery) to the mixed plaice and sole fishery in the southern part of the North Sea.

7. OVERRIDING CONSIDERATIONS OF THE OPTIONS

We have not identified any aspects from TAC and effort control that can be identified as unnecessary.

8. ENVIRONMENTAL EFFECTS OF THE OPTIONS

Details of the biological evaluation, including a full description of simulation methodology and complete results, can be found in Annex B: *Biological management strategy evaluation of the multi-annual management plan for North Sea plaice and sole*. A description of the methodology used to obtain stock recruit function fits and relative likelihoods of candidate models is presented in Annex C: *Long term Equilibrium evaluation*, that includes an evaluation of Stock-Recruitment (S-R) fits using a Bayesian approach to multiple model selection.

For both plaice and sole stocks additional biological scenarios were tested to determine whether or not the results of the evaluation were sensitive to the assumptions of initial starting condition and underlying stock productivity (stock recruit function). All biological scenarios were run assuming that the multi-annual plan would be applied in its current form. If the results are robust to these uncertainties, then management options can be analysed based on the results from the base case underlying biology. In addition to these alternative stock assumptions, an 'worst case' recruitment scenario was also conducted to specifically evaluate what would happen in the unlikely event of stock collapse due to sustained low levels of recruitment.

Tables 8.1 and 8.2 show all the scenarios evaluated, divided into biological and management scenarios, respectively. Scenario Set B1 is the base case biological

model. For both stocks, the starting point of the simulations comes from the most recent accepted ICES assessment (XSA model fits) of the stock. Recruitment is generated using the estimated model fits and uncertainty for segmented regression (hockey stick) and Ricker stock recruit functions from the Bayesian analysis presented in Annex C. Each iteration uses one of the two stock recruit functions, with the total proportions of these two functions determined by the likelihood of fits (see Annex C for a full description).

Base case

Under the base case scenario, (Table 8.1 option B1) both stocks show long term increase in both SSB and TAC. For plaice, the initial F is below the target level so the management is based on the target F straight away. This generally results in TAC increases limited by the maximum allowable TAC change for the first few years, and F only increases slowly towards the target level because of this constraint. As a result, the F reduction value used in the plan is seldom applied for plaice. For sole, the initial F is above the target level so management in the first few years applies the F reduction to reduce F towards the target value. The combination of increasing SSB and decreasing F lead to a more slowly increasing TAC for sole compared to plaice and as a result the TAC change limit is applied less frequently .

Alternative starting value

The alternative starting points for plaice (Table 8.1 option B2) do not appear to have a notable effect on the stock in the long term. Short term differences in TAC and SSB and the amount of time until the target F is reached do vary, but the trend of increasing stock size and TAC are the same in all cases, even for the poorest starting point (SCA 5th percentile). For sole, the XSA starting point (base case) represents the lowest initial stock size, though also a slightly lower F than the 5th percentile of the SCA. The impact of starting point is the same as for plaice. Given these minor short term differences but coherence in the long term trends, and the fact that the base case for sole essentially is the poorest viable starting point, it is reasonable to use the XSA assessment values as the starting points for evaluating management option scenarios.

Sensitivity to assumptions of mean recruitment

The Base line scenario includes both Ricker and hockey stick models with varying coefficients in order to include uncertainty in the S-R dynamics. Nevertheless, to evaluate the possibility of one form being dominant the relationships were selected individually for a set of scenarios, also including a Beverton and Holt S-R scenario. In addition to this, the sensitivity to the relationship between stock size and recruitment was evaluated by using geometric mean recruitment from three different recruitment 'regimes' (low 1957-1972, mid 1994-present, and high 1973-1993) (Table 8.1 option B3 and B4 respectively).

Table 8.1. Biological scenarios evaluated in the management strategy evaluation of the North Sea plaice and sole multi-annual plan.

Scenario Set	Scenario	Simulation Settings		Biology Settings		Management Settings				
		# Iterations	Final Year	Starting Point	Stock-Recruit Function	Ftar PLE	Ftar SOL	TAC Change limit	F Red.	Effort Limit.
B1	BC_Bayes	100	2030	XSA	Bayes	0.3	0.2	0.15	0.1	NA
B2 ¹	AltSP_SCA_05	100	2025	SCA 5 th %ile	segreg	0.3	0.2	0.15	0.1	NA
	AltSP_SCA_50	100	2025	SCA median	segreg	0.3	0.2	0.15	0.1	NA
	AltSP_SCA_95	100	2025	SCA 95 th %ile	segreg	0.3	0.2	0.15	0.1	NA
	segreg	100	2025	XSA	segreg	0.3	0.2	0.15	0.1	NA
B3 ¹	ricker	100	2025	XSA	ricker	0.3	0.2	0.15	0.1	NA
	bevholt	100	2025	XSA	bevholt	0.3	0.2	0.15	0.1	NA
	AltSr_L	100	2025	XSA	GeoMean Low	0.3	0.2	0.15	0.1	NA
B4 ¹	AltSr_M	100	2025	XSA	GeoMean Mid	0.3	0.2	0.15	0.1	NA
	AltSr_H	100	2025	XSA	GeoMean High	0.3	0.2	0.15	0.1	NA
B5	tarCrash_Recov	100	2030	XSA	Minimum/segreg	0.3	0.2	0.15	0.1	NA
	tarCrash_Recov_25chng	100	2030	XSA	Minimum/segreg	0.3	0.2	0.25	0.1	NA
B6	Both_Eff	100	2030	XSA	segreg	0.3	0.2	0.15	0.1	None
	Least_Eff	100	2030	XSA	segreg	0.3	0.2	0.15	0.1	Least
	MostSol_Eff	100	2030	XSA	segreg	0.3	0.2	0.15	0.1	Min(Sole,Most)

¹=Incorrect Bayes proportions in base case comparison run

Table 8.2. Management scenarios evaluated in the management strategy evaluation of the North Sea plaice and sole multi-annual plan.

Scenario Set	Scenario	<u>Simulation Settings</u>		<u>Biology Settings</u>		<u>Management Settings</u>			
		# Iterations	Final Year	Starting Point	Stock-Recruit Function	Ftar_PLE	Ftar_SOL	TAC Change limit	F reduction
M1 ²	HCR_Ftar	100	2025	XSA	segreg	0.25	0.35	0.15	0.1
	HCR_TACchng	100	2025	XSA	segreg	0.3	0.2	0.25	0.1
	HCR_Fred	100	2025	XSA	segreg	0.3	0.2	0.15	0.15
M2	Ftar_Bayes	21	2030	XSA	Bayes	0.23	0.35	0.15	0.1
	Ftar_15	21	2030	XSA	Bayes	0.15	0.15	0.15	0.1
	Ftar_25	21	2030	XSA	Bayes	0.25	0.25	0.15	0.1
	Ftar_rev	21	2030	XSA	Bayes	0.2	0.3	0.15	0.1
M3	Ftar_MSX	100	2030	XSA	Bayes	0.23	0.2	0.15	0.1
	Ftar_ICES	100	2030	XSA	Bayes	0.2	0.22	0.15	0.1
	Ftar_25	100	2030	XSA	Bayes	0.25	0.25	0.15	0.1

¹=Incorrect Bayes proportions in base case comparison run

²=Compared with segreg as a base case

The use of the Ricker stock recruit relationship has the biggest impact on results due to the reduction in recruitment experience as the stocks increase in size. The difference is more noticeable in the plaice stock due to the current large biomass, the current SSB for the sole stock is further away from the tail of the Ricker curve so reduced recruitment is not encountered. While potentially possible, the biological hypothesis behind the Ricker relationship is thought to be poorly supported for these flatfish stocks, and there is a general lack of trend in the stock-recruit pairs. This supports the use of the Bayesian model fits and the use of stock recruit relationships in proportion to their estimated likelihoods.

The differences in absolute level of recruitment between the three regimes are negligible for the sole stock, but are greater for the plaice stock. The impact of this is as expected, with long term stock size and TAC reduced under the low recruitment regime and increased in the high recruitment regime. However, the different levels of recruitment do not affect the trends in stock development and the multi-annual plan can still effectively keep the stock within safe biological limits under any of these recruitment regimes.

Conclusion on biological scenarios

Under these alternative biological scenarios the long term trends in stock development and TAC did not show any notable differences that would invalidate the use of the base case scenario. Therefore these results suggest that the base case scenario is adequate to evaluate the performance of alternative management options. Alternative management scenarios looked at the likely impacts of varying aspects of the multi-annual plan on the stock and the fishery. These included different candidate F targets for each stock, increasing the allowable annual TAC change, and increasing the annual F reduction percentage. The results of these scenarios are presented in sections 8.1 - 8.3 and Tables 8.3 and 8.4

8.1. Evaluation of the effects of the multi-annual plan options on the fishery

For both stocks, the greatest effect on long term performance came from choosing different F target values (scenario sets M2 and M3, Table 8.2) in the plan (Tables 8.3-8.4). Short term performance was affected more by changes in the allowable TAC variation in the case of plaice, or the size of annual F reduction steps in the case of sole (scenario set M1, Table 8.2).

Increasing the size of F reduction steps has no effect on the plaice fishery because current F is already below the target levels. Increasing the limit in annual TAC change leads to greater catches in the short term (and accompanying SSB reduction), but similar long term values to the current TAC change level. Alternative F targets examined over the range from 0.2 to 0.3 all lead to similar long term TAC values (because these values lie on the flat top of the Fmsy distribution, Annex C). However, below $F=0.2$, at for example 0.15, there is a long term reduction in catch. Comparing target Fs under the plan with equilibrium yields (Table 8.3) shows how under the plan with the inter-annual constraint on TAC change landings are built up for the future as the stock rises (these are then depleted over time). The equilibrium conditions have

no such constraint and just illustrate the effect of changing the target F around the maximum of $F=0.23$. In all cases risks are negligible.

For sole reducing F in 15% steps brings F down to the management target level a few years (2-4) sooner than 10% reductions. This obviously comes at the cost of reduced level of short term TAC in comparison to the 10% reduction option, though, TAC still increases in the short term. Beyond the short term there is no difference, as target F is the determining factor of yields. The TAC change limits for sole are seldom applied and hence increasing the allowable change has little to no effect on the fishery in the short or long term. However, in the 'worst case' poor recruitment scenario (see section 8.2) a greater TAC change limit can mitigate the likelihood of negative impacts. Alternative F target values in the range 0.15 to 0.35 result in both short term and long term differences in TAC. An F target of 0.15 produces lower TAC in both the short and long term, while a F target of 0.3 provides higher short term TACs, slowly becoming more similar to the long term TACs from F targets in the 0.2-0.25 range. There is a short term difference between 0.2 and 0.25, though in the long term this is less substantial (0.25 slightly higher). . Comparing target F s under the plan with equilibrium yields (Table 8.4) shows how under the plan with the inter-annual constraint on TAC leads to some increase in TAC over time but also contributes to higher risks than the equilibrium exploitation with no inter-annual constraint (see also Section 8.2).

Comparability of MSE and Equilibrium simulations

Tables 8.3 and 8.4 (and the graphs in Annex B and C) show yields and risks from two independent simulations. The differences in the results are negligible in the case of NS sole (Table 8.4), where catches and landings are equivalent. However there are differences in the magnitude of landings of plaice (Table 8.3) that are greater than would be expected due to different computational approaches. Investigations have been carried out into how these differences occur and two sources of difference between the simulations have been identified. There is a small difference in recruitment modelling; the management plan (MSE) uses a subset of 10% of the models used in the equilibrium evaluations. This small difference very slightly influences risks and SSB but as SSB is well above B_{lim} near $F = F_{msy}$ and risks are all zero, the impact is negligible and can be ignored. These differences in landings are small in the context of the variability in recruitment. The absolute values of landings should be treated with caution, however, the comparison of landings between target F s and over years is expected to be illustrative of the relative changes to be expected. An earlier version of this report issued without an ISBN number contained larger catch values in Table 8.3 which were erroneously calculated for the MSE the values given below are corrected.

Table 8.3. Plaice yields and likelihoods of meeting WKOMSE precautionary criteria (risk to stock) under different targets Fs in the multi-annual plan and from the equilibrium analysis (Annex c). (For scenarios that were run with less than 100 iterations, it is not possible to adequately estimate the risk to the stock, so NA values are given.)

F	Yield		Risk			Bayesian equilibrium values		
	ST (2011-2015)	MT (2016-2025)	ST (2011-2020)	MT (2016-2025)	LT (2021-2030)	Yield	Risk <Blim	Risk <Bpa
0.15 [§]	72863	101979	NA	NA	NA	80345	0.00	0.00
0.2 [§]	87639	111468	NA	NA	NA	85997	0.00	0.00
0.22	*	*	*	*	*	86691	0.00	0.00
0.23	95520	113152	0	0	0	87038	0.00	0.00
0.25	99344	112885	0	0	0	87732	0.00	0.00
0.3	107451	111376	0	0	0	86734	0.00	0.00
0.35	*	*	*	*	*	83743	0.00	0.00

§ based on only 21 replicates (too few to estimate risk) * Not run for this stock.

Equilibrium and MSE values of landings are not directly comparable see text above

Table 8.4. Sole yields and likelihoods of meeting WKOMSE precautionary criteria (risk to stock) under different targets Fs in the multi-annual plan(Annex B and from the equilibrium analysis (Annex c). (For scenarios that were run with less than 100 iterations, it is not possible to adequately estimate the risk to the stock, so NA values are given.)

F	Yield		Risk			Bayesian equilibrium values		
	ST (2011-2015)	MT (2016-2025)	ST (2011-2020)	MT (2016-2025)	LT (2021-2030)	Yield	Risk <Blim	Risk <Bpa
0.15 [§]	14365	15904	NA	NA	NA	16644	0.00	0.00
0.2	14512	17687	0.1	0.05	0.02	18202	0.00	0.00
0.22	14531	18215	0.1	0.05	0.02	18595	0.00	0.01
0.23	*	*	*	*	*	18792	0.00	0.01
0.25	14615	19151	0.1	0.06	0.06	19185	0.00	0.02
0.3	14645	20236	0.14	0.14	0.19	19694	0.01	0.08
0.35 [§]	15886	20568	NA	NA	NA	19608	0.04	0.19

§ based on only 21 replicates (too few to estimate risk) * Not run for this stock.

Mixed fisheries issues

Most of the scenarios examined assumed that the fleets will fish up both TACs while avoiding catching overquota fish. However, it is worth considering the likely impacts of mixed fishery dynamics on the success of the multi-annual plan. In order to examine the possible effect of the mixed fishery, three scenarios of fishing effort were examined in a further analysis. These scenarios (Table 8.1, scenario set B6) cover a range of potential reactions to the TAC of one of the stocks being caught before the TAC for the other has been caught. In this case the fishery will either stop (*Least_Eff*: i.e. the mixed fishery is limited by the least effort required), continue while avoiding catching the other by some technical or spatial changes in fleet behaviour (*Both_Eff*: i.e. catches of stocks considered independent, both TACs caught) or continue to fish until the TAC of both stocks is caught, discarding the over quota catch caught for the other stock (*MostSOL_Eff*: i.e. effort only limited by the most demanding TAC). Because sole is the main (most profitable) contribution to the landings, it is more likely that if sole is limiting (i.e. low TAC that can be caught with less effort) fishing

for plaice only does not occur, simply because this would not be profitable. In the unlikely situation that there is a big discrepancy between the TACs, and plaice fishing would still be profitable, then plaice can be caught cleanly by spatial changes or technical restrictions. There are areas where plaice is present but not sole (e.g. further north in the North Sea). Also, changing gear used can prevent large overquota of sole while still landing plaice (e.g. shift from 80mm to 100mm mesh size). Considering these mitigating factors, the final scenario considers that fishing will continue until all sole is caught, but extra effort to catch plaice beyond this will not impact on the sole stock.

Initially more effort is required to land the sole TAC than the plaice TAC but this reverses after as sole F decreases and plaice F increases according to the plan. As plaice TACs increase more rapidly than those of sole, accompanying opposite trends in F (decrease in sole and increase in plaice), this leads to the TAC of plaice requiring more effort to land in the long run. This is a more tractable and favourable situation for the mixed fishery to be in because overquota of sole can be more easily avoided than that of plaice. None of the assumptions of mixed fisheries behaviour invalidated any of the previous conclusions, in fact suggesting that for plaice the management plan is likely to be more precautionary.

8.2. Evaluation of the effects of the multi-annual plan options on the stock

The general pattern of stock development of plaice under the various management scenarios evaluated was an increasing trend in SSB in the short term (roughly 5 years) followed by a leveling off of median SSB. Alternative F targets in the 0.15 to 0.3 range lead to the stock stabilising at different levels of SSB, all above B_{pa} and precautionary with regards to the limit reference points in the short and long term. Given the healthy condition of the plaice stock and the current low levels of F being exerted on the stock, these low risk levels are not surprising. The estimates of F_{msy} from the long term equilibrium analysis method (Annex C), updated with 2010 assessment values, gives a value for NS plaice of $F=0.25$ (Table 8.3).

The sole stock also shows a general pattern of increase under the scenarios examined, although this increase is slower initially and it takes longer for the stock to stabilise at a higher level (roughly 10 years). Although the sole stock is currently believed to be slightly above B_{pa} , F remains high and this has implications on stock growth in the short term. Because there is a risk of poor incoming recruitment leading to the stock dropping below B_{lim} , the multi-annual plan was not found to be precautionary in the short term (i.e. first 10 years), for most of the management option evaluated. Increasing the reduction of F to 15% steps brings F down to the management target level quicker and allows for an increase in stock size. This increases the likelihood of the management plan being precautionary in the medium term (<5% risk according to WKOMSE criterion), although long term differences are negligible. The risk at an F target of 0.15 or 0.2 is similar, with both being precautionary for 2016-2025 and longer term, but not in the short term. An F target of 0.25 does not lead to stock levels that can be considered precautionary for any of the three ten year time periods examined (6% chance of not being precautionary in the last ten years, 2021-2030). This indicates that the estimated F_{msy} (ignoring risk) for this sole stock, in the region of 0.32 (Table 8.4 using the method of Annex C updated with 2010 assessment values) poses too high a level of risk to the stock, as any F targets above 0.3 were not

found to be precautionary over any time period. It is considered that it is important to take the risk into account when setting the target F for sole.

Evaluation recovery in the unlikely event of stock collapse

Given that the plaice stock is currently considered to be in a very healthy state, it is useful to examine a scenario in which the stock falls into a less healthy state to see how the multi-annual plan is able to perform under these conditions. Once the F target had been met or passed, the scenario considered reduced recruitment to fluctuate around the minimum observed level over the entire time period until the stock reaches 75% of Blim before resuming the usual S-R function. This drives the stock to a very low level and then still has 2-3 very poor incoming year classes. It should be noted that such a catastrophic recruitment failure has never been observed for these stocks over the greater than 50 year time series. Hence probabilities of collapse should be considered as relative measures of the performance of candidate management options rather than possible likelihoods of risk to the stock.

With the current healthy state of the plaice stock and low F, it takes about 20 years of minimum recruitment to drive plaice stock down to 75% of Blim. Once this has occurred, 17% of stocks collapse (though this is reduced to 13% if a 25% TAC change limit is allowed). Such a prolonged recruitment failure is unlikely and the high level of recovery from this very poor stock condition implies that the multi-annual plan can be considered robust to poor recruitment in the short (given the strong status of stock) and long term. The length of the poor recruitment period required to drive the stock down to low levels would in practice also allow time for the management of the stock to react in order to avoid poor stock status.

The sole stock is more easily driven to low biomass levels. Target F is achieved in approximately 5 years and following this 5-10 years of minimum recruitment is required to reduce the stock below 75% of Blim. Thereafter most stocks collapse (65%). The likelihood of collapse reduces notably if 25% TAC change limits are applied (39%). The multi-annual plan currently contains a clause allowing for more reactive management beyond the rules of the plan should the stock fall outside of safe biological limits (in relation to precautionary reference points). However, in the case of sole, this may be too late. Bpa is near to Blim and it has been observed in the past that the stock can change from above Bpa to below Blim in a single year. Fpa for this stock is also above the current management target so following the multi-annual plan HCR should keep the stock within safe biological limits with regards to F. However, in the case of a few poor year classes, using the precautionary reference points as a basis for reactive management may not be sufficient. It seems a greater ability to react to repeated poor incoming recruitment is required in the management plan, for example a recruitment reference level that a recent average can be compared with to trigger a greater reduction in TAC.

8.3. Evaluation of the effects of the multi-annual plan on the ecosystem.

GES objectives are hard to define, and so have been difficult to build into the plan. Some potential GES targets are presented in Annex B (mean age and age diversity), but do not appear to be meaningful as reference points indicating a 'healthy' stock

according to these criteria are lacking. Having a lower proportion of discards in the catch of plaice could be seen as a more ecosystem-friendly result of the management plan. Results show, as expected, that a decrease in F level (and the associated effort required to land the TAC) leads to a lower proportion of discards in the catch. Over the range of F targets evaluated, all showed a short term decrease in discards proportion, levelling off at a lower level in the region of 20-30% discards.

Likewise, a reduction in effort, limiting it below 2006 levels as specified in the plan, is likely to reduce the overall ecosystem impact of the dominant beam trawl fishery. It should also be noted that in recent years a small fraction (< 5%) of the Belgian and Dutch beam trawl effort was carried out by “twin rig” gear. The environmental impact of this type of fishery in terms of fuel consumption is clearly better compared to the beam trawl. This is also the case for seafloor penetration although twin rigs have a much larger swept area and as such a larger but less intense impacted area. Two vessel using the twinrig have also obtained the MSC-label.

9. SOCIAL AND ECONOMIC EFFECTS OF THE PLAN

Two economic studies are available, a report prepared by MRAG which uses a simple stochastic biological model with no stock recruit function and assumptions of stability in fishery the fisher, the second includes varying dynamic in the fishery, a stock recruit function but without stochastic variability. These two studies are summarised in section 9.1 and 9.2 respectively

9.1. Summary the MRAG lead economic and social impact assessment of North Sea flatfish plaice and sole.

The MRAG report provides an economic and social impact assessment of multi-annual management plan scenarios for North Sea plaice and sole. Quantitative impacts were analysed using a bio-economic model, substantiated with qualitative information on impacts informed by stakeholder consultation.

The biological component of the model comprised of single species age structured stock projections coded in Fisheries Libraries in R (FLR). Projected spawning stock biomass and TACs for the North Sea plaice and sole stocks were used as input to a modified version of the latest EIAA model. Future SSB and TACs for other stocks were set at current levels. Model runs were undertaken using EIAA reference periods of both 2005-2007 and 2008, with output for economic and social indicators provided for 2010, 2015 and 2020.

The biological model assumed variable recruitment similar to historic recruitment without a S-R model, but with varying exploitation rates. This variability in supplies of fish depend only on yield per recruit concepts of growth and mortality but the with the addition of stochastically varying values for recruitment.

Data on the number of North Sea flatfish dependent vessels and both their total landings value and North Sea plaice and sole landings dependency were provided by appropriate member state contacts. Economic costs and earnings data for North Sea flatfish dependent vessels required for the EIAA model were not available for the fleet segments. These data were estimated using segment specific economic costs structures presented in AER reports (Anderson et al., 2009). For Denmark, due to the

complexity of fleet structure (in terms of multiple areas fished by a single segment), and Belgium it was not possible to identify North Sea flatfish dependent vessels so economic costs and earnings data for the overall AER segment were used.

26 vessel segments were identified as having North Sea flatfish dependency with the 6 most dependent being: German TBB 24-40m (69 % landings value dependency on North Sea flatfish); Dutch TBB 12-24m (71%), TBB 24-40m (70%) and TBB >40m (77%); and, UK DTS 00-12m (81%) and TBB >40m (75%).

Large increases of SSB were projected for both North Sea plaice and sole under the current management plan, with increases of 54% and 62% by 2020 compared to 2008 levels for plaice and sole respectively. The TAC for North Sea plaice increased by 66% by 2020 compared to 2008, with a 21% increase in TAC for North Sea sole.

Table 9.1 summarises model output for selected indicators for the status quo scenario using a reference period in the EIAA model of 2005 to 07 i.e. continuation of the current management plan and no other changes. The output presented in Economic and social impacts on on-shore dependent employment and gross value added in the ancillary and processing sector were also analysed for the 6 member states, using a multiplier based approach.

The EIAA model reference period of 2005 to 2007 was selected in order to exclude 2008 data and to remove the adverse impacts on fleet segment economic performance observed in 2008, which were due to factors external to the management plan; most notably the increase in fuel price. However fuel prices are likely to increase in the future, with changes in fleet behaviour and economic costs structure to adapt to this increase. Consequently model runs using a reference period of 2008 were also done to analyse impacts on the catching sector including adaptation to increasing fuel price. The general trends in results described above also hold for model runs with the 2008 reference period.

Table 9. is for North Sea flatfish dependent vessels only, with the exception of Danish and Belgian segments for which the output is for the whole AER segment. (Thus for just these segments plaice and sole from any other area cannot be separated from the catch in the NS and is assumed to scale along with NS plaice and sole). It is also important to note that the output is reflective of each segment's total fishing operations in all fishing areas, not only the North Sea. For example, the Belgian TBB2440 segment has a relatively high value of landings in comparison to other segments. However the segment expends a relatively low level of effort in the North Sea, and the data presented is for the AER segment as a whole. Consequently the segment's North Sea flatfish dependent landings will be lower than that given in the table.

The model predicted increases in volume of landings for the fleet segments, in line with the increases in TAC. However some segments experienced declining value of landings due to decreases in landing prices. The large increases in SSB for both North Sea plaice and sole resulted in large reductions in effort and effort related costs for the fleet segments per unit of landings due to increases in catch per unit effort for the fleet segments. This resulted in increases in gross value added and net profit margin. Absolute effort levels for all fleets decreased due to the increase in catch per

unit effort, resulting in reductions in full time equivalent employment in the catching sector.

The degree of improvement in fleet segment specific economic performance for all indicators was primarily influenced by the segment's dependency on North Sea flatfish, with stronger increases for more heavily dependent segments. Furthermore strong improvements in economic performance were predicted for segments with higher dependency on North Sea plaice due to the larger increase in catch.

Economic and social impacts on on-shore dependent employment and gross value added in the ancillary and processing sector were also analysed for the 6 member states, using a multiplier based approach.

The EIAA model reference period of 2005 to 2007 was selected in order to exclude 2008 data and to remove the adverse impacts on fleet segment economic performance observed in 2008, which were due to factors external to the management plan; most notably the increase in fuel price. However fuel prices are likely to increase in the future, with changes in fleet behaviour and economic costs structure to adapt to this increase. Consequently model runs using a reference period of 2008 were also done to analyse impacts on the catching sector including adaptation to increasing fuel price. The general trends in results described above also hold for model runs with the 2008 reference period.

Table 9.1 Results of the bio-economic model by fleet segment for selected indicators in 2005 - 2007 and 2020.

		2005-2007				2020			
MS	Segment	Income (mln)	GVA (mln)	Net Profit Margin	Employment (FTE)	Income (mln)	GVA (mln)	Net Profit Margin	Employment (FTE)
BEL	TBB1224	16.4	3.5	-35%	172	15.5	3.7	-37%	154
BEL	TBB2440	67.8	20.4	-12%	338	66.6	31.5	-11%	239
BEL	DFN1224	1.0	0.2	-40%	15	0.9	0.3	-49%	11
BEL	DTS2440	4.5	3.1	24%	19	4.6	3.3	26%	17
DEU	TBB2440	6.2	2.8	28%	20	5.8	3.5	41%	13
DEU	DTS1224	6.3	3.9	12%	28	7.1	4.8	17%	25
DEU	DTS2440	2.5	1.8	42%	50	2.8	2.2	47%	42
DEU	DFN1224	2.6	2.0	29%	33	2.5	2.0	30%	24
DNK	PGP0012	25.7	11.9	-51%	387	25.9	12.3	-51%	380
DNK	PGP1224	27.8	18.3	3%	254	28.5	19.8	5%	228
DNK	PMP1224	20.0	11.6	0%	133	21.2	13.1	3%	127
DNK	DTS1224	55.2	30.3	-11%	518	57.1	32.7	-10%	505
DNK	PTS1224	38.5	20.1	-9%	287	39.1	20.9	-9%	283
DNK	DTS0012	1.1	0.3	-115%	20	1.1	0.3	-117%	20
FRA	DFN0012	15.4	9.9	9%	124	15.3	10.0	9%	116
FRA	DFN1224	7.2	4.4	9%	67	7.2	4.4	10%	63
NLD	DTS1224	7.2	4.5	26%	42	7.6	5.2	30%	37
NLD	TBB1224	14.2	6.0	-15%	96	12.1	6.0	-18%	61
NLD	TBB2440	37.3	9.1	-22%	211	34.5	14.7	-20%	136
NLD	TBB40XX	141.1	55.1	7%	553	128.5	71.9	15%	332
GBR	DTS0012	0.1	0.0	32%	5	0.0	0.0	38%	3
GBR	DTS1224	1.0	0.3	3%	35	1.0	0.5	10%	28
GBR	DTS2440	1.8	0.6	3%	16	2.2	1.1	13%	14
GBR	DTS40XX	1.8	0.6	-4%	35	2.2	1.1	6%	28
GBR	TBB2440	9.9	2.5	-8%	74	11.3	5.4	2%	57
GBR	TBB40XX	15.2	1.1	-37%	75	17.6	7.4	-46%	52
TOTAL		528	224	-6.7%	3608	518	278	-4.0%	2996
Increase over 2005-07						-1.8%	24.1%	2.7%	-16.9%

Economic and social impacts were also analysed for the implementation of a lower target fishing mortality (0.17) for North Sea plaice in 2012, in order to be closer in line with estimates of Fmsy proxies for the stock, as well as the requirement that the stocks should be at Ftarget by 2015. The Ftarget for sole was kept at 0.2. Initially fleet segment economic performance was worse than the status quo scenario due to the reduction in catches due to the lower target fishing mortality. However, in 2020 catches were higher with the reduced F target due to the greater increase in SSB, leading to better fleet segment economic performance compared to the status quo.

9.2. Summary the FISHRENT model economic and social impact assessment of North Sea plaice and sole.

The full details of the analysis and results are given in Annex D. This evaluation contrasts with the evaluation in 8.1 in that the fleets are allowed to adapt to changing conditions. Here the biological assumptions of the FISHRENT model are modified specifically to deliver the median response of the biological base case (Table 8.1 option 1B). No stochastic biological aspects are included in the FISHRENT model.

9.2.1. Description FISHRENT model

To simulate fleet dynamics and economic development due to the management plan in the North Sea an optimization model was build by LEI. As the basis of this model the excel model build for the EU project “Study on the remuneration of spawning stock

biomass” was used. This model (called FISHRENT) simulates values of biological and economic variables and shows explicitly the consequences of different policy decisions. The model generates basic economic indicators like gross value added, net profits. The model generates also a variety of other results, e.g. size of stocks and fleets, production costs, catches and landings.

The adapted FISHRENT model is as closely tailored to the real world as possible. The model contains both an economic and a biological module which are connected in an interface module.

Biological module

The fish stocks develop using a 2nd degree polynomial stock-growth function. The catchable biomass is determined by its growth and the realized catch, which may exceed the sustainable catch when too much fishing effort is allowed.

The stock dynamics model parameters in FISHRENT have been adapted to match the median results of the biological evaluation as closely as possible. The median biological projections of the stocks from Section 8.1. can be compared with the one simulated in FISHRENT; Figure 9.1 shows that the stock-growth function fits the projection of the stock quite closely.

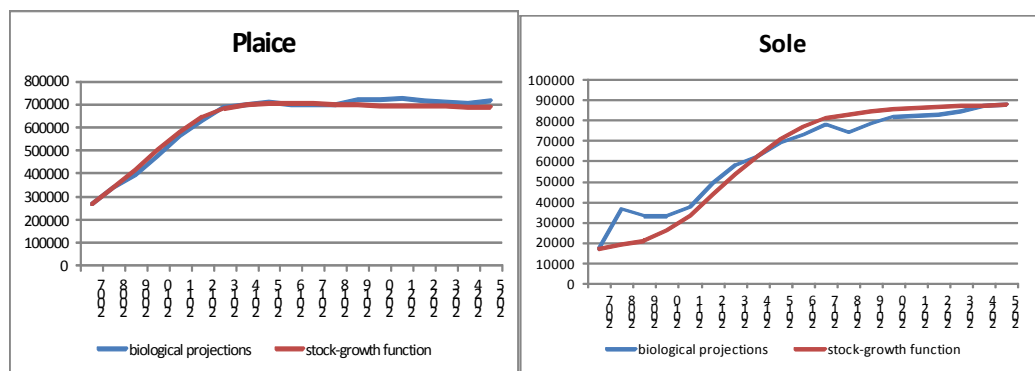


Figure 9.1 Fit of median trajectory for plaice and sole stocks under current management plan and the simulated deterministic response in the FISHRENT economic model.

Economic module

Based on the projected landings the economic module determines the expected production costs, net profit and gross value added. Changes of the fleet size are determined with an investment function, which in its turn is related to profit level of the previous year, using the relation between realized revenue and break-even revenue.

Theoretically the investments are determined by expectations of future profit, but there is no empirical data, which could be used to support such theorem in the model. Instead, perceived profitability in the preceding year is expressed as a ratio between realized revenues and break-even revenues. When break-even revenues exceed realized revenues then the fleet segment is considered unprofitable and will decrease and vice versa. This leads in some years to quite substantial changes in the number of

vessels in a fleet segment, which can be justified as vessels leaving to another segment or entering from other segments. It is assumed in the model that there are no major initial cost of adding a vessel to a segment, which you would expect if new vessels would enter the fisheries as opposed to vessel transferring from other segments.

Furthermore, it has been assumed that the active fleet will first achieve a certain minimum number of days-at-sea per vessel before the number of vessels will be expanded. This assumption was introduced to avoid large investments when existing capacity is underutilized.

Interface module

The economic and biological modules are connected through the fisheries production function. The production of the fleet is based on a Cobb-Douglas production function, where catch depends on effort and the biomass. Target species of flatfish fisheries in the North Sea are mixed. Denmark and UK have mainly segments that target solely plaice and hardly catch any sole. The Netherlands and Belgium have segments that target mainly sole and catch a significant amount of plaice as a by-product. The type of fisheries and the possibility of switching between plaice and sole as target species may very well have an impact on the success of the management plan and is therefore taken into account in the production function.

The production function is modeled as a simple Cobb Douglas function as data to empirically estimate the function was not available. The catch (excl. undersized discards) is a function of effort, stock abundance and technological progress. In contrast to the original FISHRENT model we have included the possibility of 2 types of effort: effort targeting sole and effort targeting plaice. Any vessel targeting sole is expected to catch plaice as a bycatch. Any vessel targeting plaice is expected to only catch plaice. The suitability of the Cobb Douglas function to describe the relation between effort and biomass should be further tested for each segment in the model. should be further testedA further study on estimating multi output production functions for each segment would be recommendable. This would however require individual vessel data to be available for the analysis.

9.2.2. FISHRENT Model Main Results

The model is used to determine the expected fleet dynamics in the next 25 years given the median expected stock and quota changes and related economic performance. The model shows that the number of vessels in these segments (Figure 9.2) will decrease in the first couple of years due to the reliance on sole. The reduction in the Danish segment is due to it's unprofitability and overcapacity in the segment in the base year. This does not necessarily mean that these vessels disappear from the fleet, they could also switch to a different more profitable segment. The number of operational seadays declines for several fleets segments for the first couple of years where the sole quota are limiting to production.

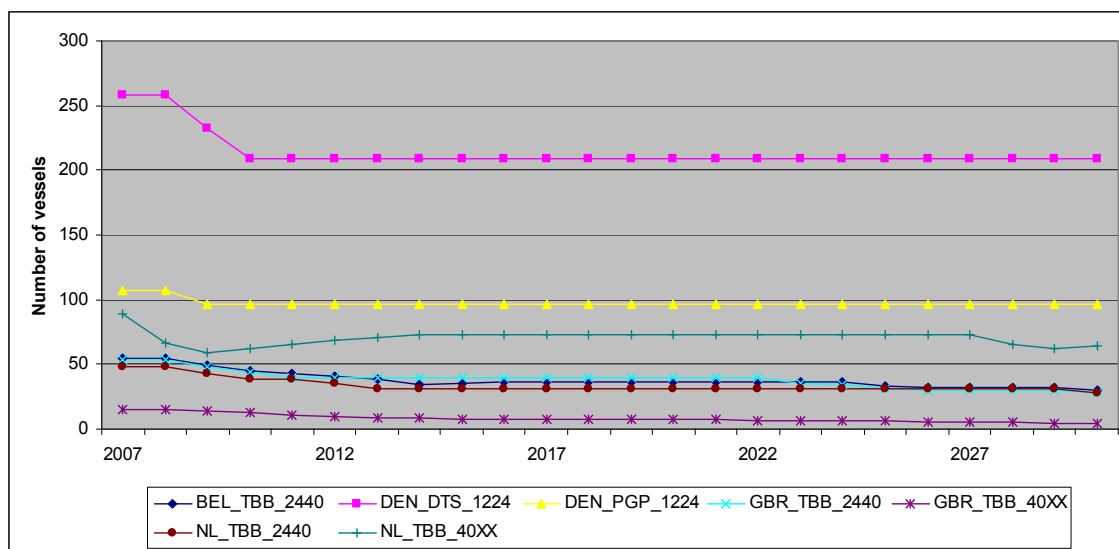


Figure 9.2 The number of vessels by fleet

The expected gross cash flow calculated as the revenues minus the variable costs are shown in the Figure 9.3. The peak in the cashflow in 2009 is due to the low fuel cost in that year. After 2009 the limiting sole quotas have their effect on the cashflow. In later years the cashflow increases again, although it is assumed that the price in sole is elastic which will cause the price of sole to decrease as supply increases which causes a decline of the cashflow in final years .

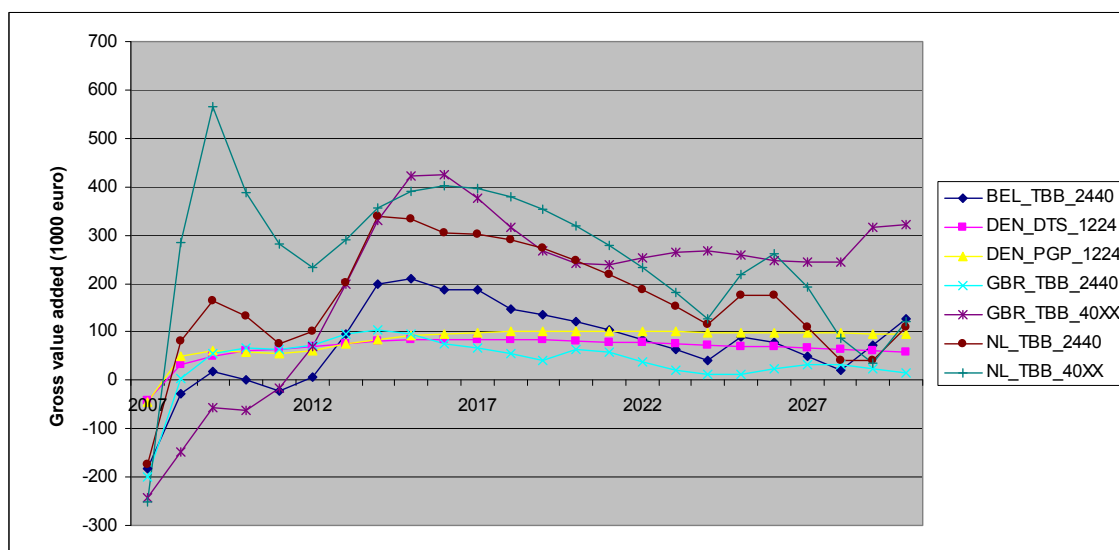


Figure 9.3. Projected gross cash flow calculated as the revenues minus the variable costs by fleet.

Some of the multi species fisheries are expected to partly shift their focus from sole to plaice at the start of the period (Figure 9.4). When the quota for sole areas no longer limiting these fisheries, they shift their effort partly back to sole. As the quota for sole are very limiting in the first couple of years, a fairly large part of the effort in this

fleet is switched to plaice. This may not be completely realistic and some more effort should be put into estimating the production elasticity's of the model.

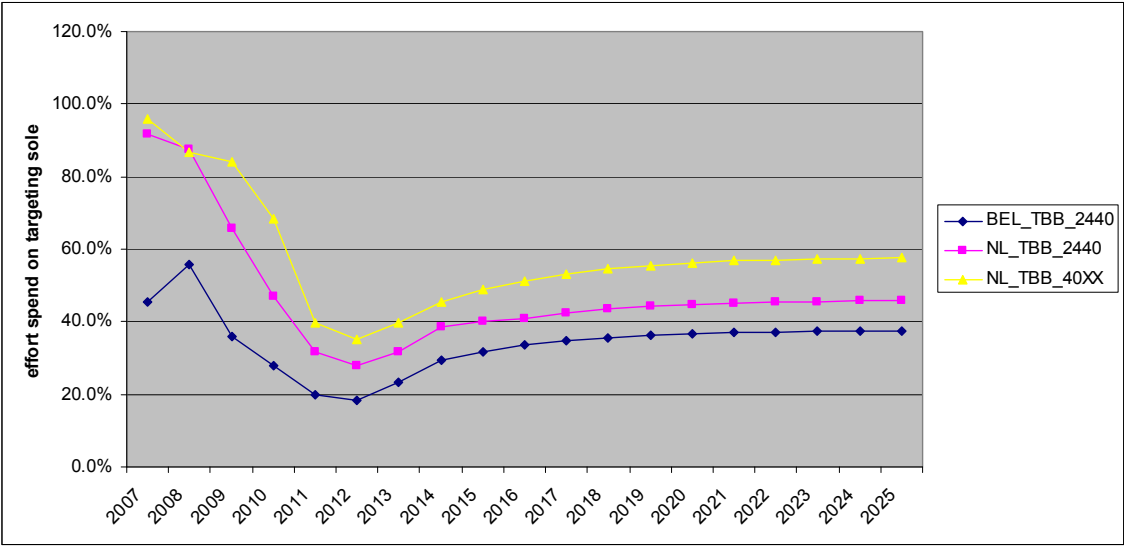


Figure 9.4 Dependence of multispecies fleets on plaice and sole expressed at the % of total available effort spend on targeting sole.

The assumption in the model that vessels are able to switch from target species has a big impact on the fleet dynamics and the profitability of the fleet, this is shown in Figure 9.5. If it would have been assumed that the fleet could not switch their target species. The profitability of especially the Dutch large beam trawl fleet would be a lot worse.

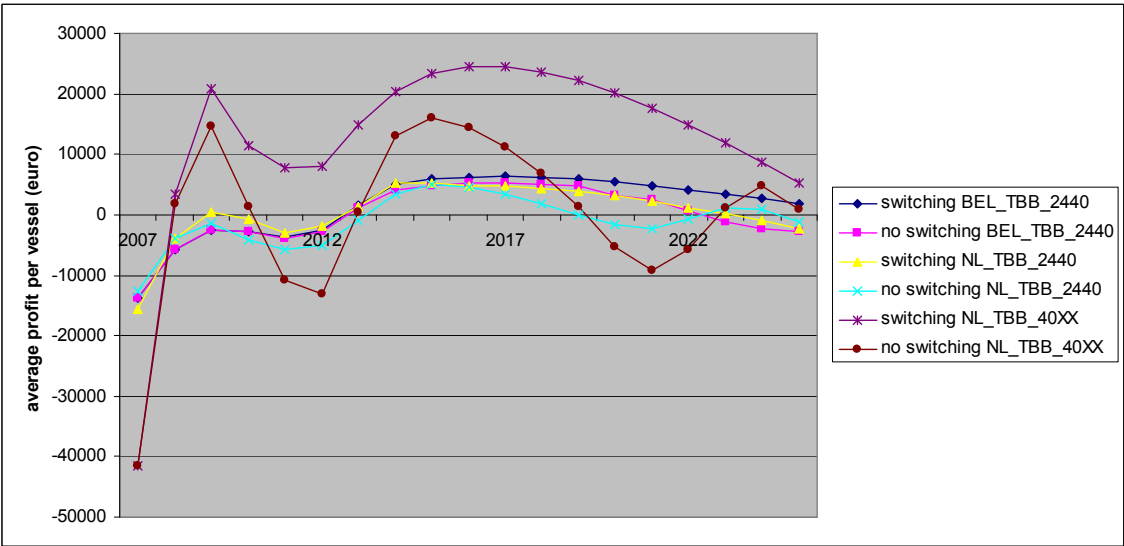


Figure 9.4 Profitability of selected fleets under switching / non switching scenarios.

The model gives an interesting approach to look at the economic consequences of the flatfish management plan in the North Sea. The possibility of specific fleet segments switching target species for part of the time is a real possibility considering that quota

for sole are expected to be limiting in the near future. However, this has regulatory consequences and may interact with the cod recovery plan (see Section 6.2. However the results and especially the switching for sole as a target species to plaice as a target species may be over estimated by the model because the TAC's calculated by the model are too limiting especially in the first couple of years. Some further research in the estimation of the TAC would be beneficial. Another interesting addition would be to include the possibility of targeting other species then sole and plaice.

10. COST EFFECTIVENESS OF CONTROL AND ENFORCEMENT

SG MOS 09-02 examined the information on control and enforcement and which concluded that implementing measures are usually in place. The main deficiencies observed concern aspects related to the effort management system and the catch registration systems in place. In particular;

- With regard to the monitoring of effort management the following are noted: Absence of system of effort reports or alternative system developed for vessel less than 15 m length; no link between VMS data and the national catch registration database; discrepancies in the national databases when crosschecking catch registration and VMS data. These issues question the effectiveness of the databases.
- With regard to the catch report reporting system (and quota management): Missing logbook data or discrepancies between logbook figures and figures in electronic data set; a considerable number of landings exceeded the permitted margin of tolerance for recorded weight of 8%; missing information or discrepancies between sales notes figures and figures in electronic data set. While observed in nearly all MS, these aspects that undermine the reliability of the catch report system.
- Moreover, it was observed by EC inspectors that the national fleets are not limited by the applicable fishing effort, especially as a result of additional days allocated to MS for decommissioning fishing vessels.

While these aspects should be addressed and the compliance improved there is no indication that control issues are a major problem for the NS plaice and sole fishery.

11. CONCLUSIONS TO THE IMPACT ASSESSMENT

The current plan can be accepted as precautionary and will reach MSY targets for both plaice and sole. There are indications that a target of $F=0.23$ for plaice would be a more appropriate F target for MSY. This might also be more in line with F target for sole (see below). While the plan for plaice appears robust to stock collapse through recruitment failure, the same is not the case for sole unless some additional action is taken. Such action is implied in the management plan but is not explicitly described. It is considered that the best trigger for remedial action should be a value for mean recent recruitment, though the most suitable period and value has not yet been determined.

11.1. Comparison of Options

The current F target for the plaice stock does not produce significantly higher long term yields relative to F s in the range 0.2-0.3. It does however result in a lower long term biomass median and therefore a potential higher risk to the stock (though all scenarios examined showed very low risk to the stock). An F target in the range 0.2-0.25 is acceptable (similar yields, but safer), and could potentially be set to 0.23 (the estimated F_{msy} for this stock using the Bayesian method, Annex C). A lower target F , in addition to reducing discard proportion and potentially reducing the ecosystem impact of the fishery, would also increase coherence with sole target. Figure 11.1 shows the mean F of the plaice stock in relation to that of the sole stock. Since the mid 1960s this ratio has been below that implied by the targets in the multi-annual plan. Assuming the sole target remains unchanged, using the long term average ratio (long term mean $F_{ple}:F_{sol} = 1.18$), would result in a target of 0.23 or 0.24 for the plaice stock, which is nearer the estimated F_{msy} level and also near to current levels of F exerted on the stock.

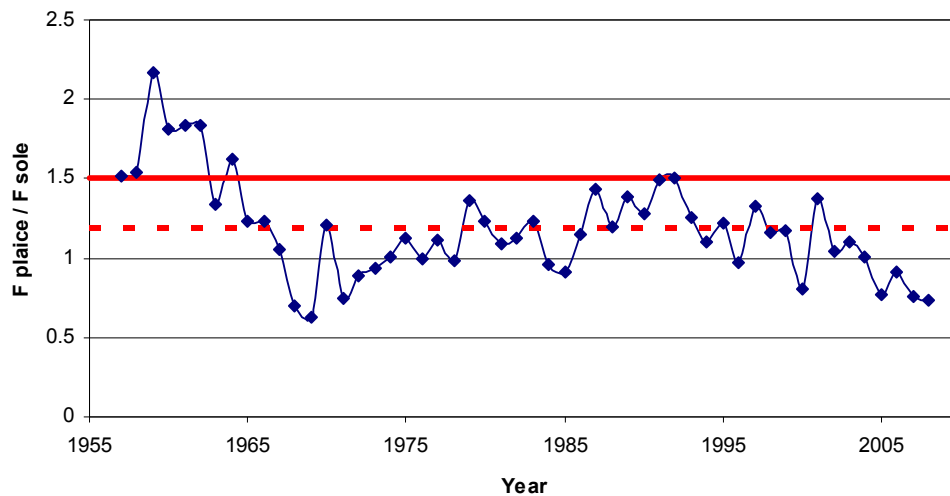


Figure 11.1. Time series of proportionality of plaice and sole fishing mortality (1957-2008), expressed as F_{plaice}/F_{sole} . The solid horizontal red line indicates the same proportionality in the target F values in the multi-annual plan (1.50), and the dashed horizontal red line indicates the mean value over the whole period (1.18).

The target F for sole should not be increased above $F=0.22$, as the difference from the current target of 0.20 is negligible it seems sensible to remain at 0.2. An increase in F target might lead to higher catches, but the risks associated with increase in target F are considered to be not precautionary ($F = 0.25$ is not precautionary).

In the ‘worst case’ poor recruitment scenario (see section 8.2) a greater TAC change limit can mitigate the likelihood of negative impacts. In conclusion it is not necessary to change the limits in the plan, but obtain a better criteria under which increases changes to management can be applied if the stock is perceived to be declining too quickly to too low a an SSB. So potentially there is a need for a different clause

(besides safe biological limits as currently stated in Article 18 of the multi-annual plan) for 'exceptional circumstances' (i.e. when to increase reactivity), for example, an alternative biomass point slightly higher than Bpa (which is very near to Blim) or if mean recruitment level over a recent time period is below a certain level.

Increasing the allowable change in TAC, to get nearer target F more quickly might be beneficial in the medium term, as the current plan is not precautionary in short term, but risks reduce in medium term. Such an approach would allow the stock to recover more quickly to give a healthy springboard to launch sustainable, high yield management.

Combined considerations

The mixed fisheries scenarios suggest that because of technical measures that could increase plaice catch while limiting sole impact, the coupling of both for the start of stage 2 of the plan is restrictive. Plaice has been within safe biological limits for more than two consecutive years, but exploitation is held back by the state of the sole stock. Currently the target Fs are not well aligned and the change in target F for plaice suggested above may help this. The long term matching of these targets will always be a potential problem. As a general strategy it is thought to be sensible to keep plaice SSB high because if plaice becomes limiting catches of sole may have be reduced to protect plaice. In contrast it is still possible to catch plaice outside the areas where sole it caught this if sole becomes limiting there is scope to continue to catch plaice. If the current situation with regards to stock status was reversed it would be necessary to hold back the start of stage two, but in the current situation, reining in the plaice fishery has limited benefit to the state of the sole stock.

Interannual limits to TAC change

There is no specific need to alter the interannual limit to TAC change. An annual TAC change of greater than 25% has limited impact and thought to be too great. Increases up to 25% are make the exploitation safer from a biological perspective.

11.2. Effectiveness: best placed to achieve the objectives (select appropriately just to relate to the objectives given above)

Economic returns are generally expected to be better at or below MSY targets so slightly lower plaice target might give better long term returns.

11.3. Efficiency: cost-effectiveness

No information on costs of enforcement.

11.4. Consistency: limiting trade-offs across the economic, social and environmental domains

A mismatch between sole and plaice F targets is the most likely source of problems. So while on their own the existing targets are generally considered to be correct reducing the plaice target would be in any case be in a helpful direction.

12. FORWARD LOOK TO EVALUATION

Better fleet segmentation of data to split plaice and sole for management advice.

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ANNEX A FRAMEWORK FOR IMPACT ASSESSMENTS REPORT

The following layout describes the minimum aspects to be considered in preparing an Impact Assessment. In addition the meeting should consult the Table in Appendix I which details a more complete list of relevant questions for impact assessments, where appropriate additional aspects should be added.

1. PROBLEM STATEMENT

The Commission should provide scope and limits of problem to be addressed

Why there is a need to react and where appropriate link this to background studies or information.

2. DEFINE OBJECTIVES : GENERAL / SPECIFIC / OPERATIONAL

General objective: will be CFP (statement provided by the Commission)

Specific objective: what the objectives are in terms of changes and expectations of outcomes with timescales (for example achieving exploitation target in X years)

3. IDENTIFY TACTICAL METHODS

Describe the operational objectives (which may be option dependent)

Effort changes / or Capacity / or TACs with interannual stability criteria.

Select the different approaches that are to be considered.

These should be predefined by Commission and limited to a specified range confirmed at the scoping meeting.

4. OVERRIDING CONSIDERATIONS OF THE OPTIONS

Identify if there are significant parts of the any options that are unlikely contribute to the overall objectives

Identify if in the opinion of the evaluators the options are likely to be able to deliver the objectives of the plan.

5. ENVIRONMENTAL EFFECTS OF THE OPTIONS

5.1. Evaluation of the effects of the multi-annual plan options on the fishery

Show what is expected to be the resulting impact on landings and the fleet of any of the following aspects that are affected by the plan options:-

- Catch and effort limitations – either through TAC or effort management expected to result from the different options.
- Technical measures – eg. Closed areas, gear restrictions, etc. that are included in the options.
- Control and enforcement measures proposed – eg. Entry and exit rules, allocation rights, etc. and any exemptions,
- Capacity management measures that are included in the options,

What is the expected fishery response to the different options? The response strategies of the fleets include possible shifts to other stocks or species, to other gears or métiers, changes in discard and slippage and other behavioural issues.

5.2. Evaluation of the effects of the options on the stock

This section should be adapted to any particular plan and stock.

- Evaluating the stock response to the changes in the fisheries resulting from the plan - will the options deliver their own internal objectives with respect to the stock?
- Evaluating whether the values of target and other reference points referred to in the plan are consistent with current knowledge and the objective of achieving MSY by 2015.
 - Are the reference points in the plan appropriate given the current information on stock status and dynamics?
 - Are the options likely to achieve F_{MSY} by 2015? If not, why? (see note 1)
 - Are the options likely to be considered precautionary. If not, why? (see note 2)
 - Is there a need to propose all the measures in the plan to make it capable of achieving the objectives? If so is STECF able to propose simpler options for a better plan to achieve stock – specific objectives?

5.3. Evaluation of the effects of the multi-annual plan on the ecosystem.

- What impacts of the different options plan on the ecosystem can be identified? Ecosystem impacts might include changes in discarding practices, by-catch rates, and catch of non-target species, habitat degradation, etc.
- What will be the effect on agreed indicators or descriptors that are directly (and where possible indirectly) affected by the options.

6. SOCIAL AND ECONOMIC EFFECTS OF THE PLAN

6.1. Data and Calculation of Indicators

- If there is no explicit socio-economic objectives defined by the multi-annual plan the options should be measured against the general socio-economic objectives as stated in the CFP.
- Will the explicit socio-economic objective defined by the multi-annual plan be met by the different options.
- The social and economic state of the fleets exploiting the stock or stocks concerned can be assessed using appropriate indicators, i.e. those proposed in the plan or those given below which include those proposed by STECF in the April 2009 plenary report.

Yearly economic indicators

- *Value of landings* ~ revenue from sale of fish.
- *Market price* ~ ex-vessel price and where possible price along the chain.
- *Gross Cash flow* ~ income minus all operational costs (excluding capital costs).
- *Break even revenue* ~ long term break even revenue. The income (revenue) level at which economic profit is zero.
- *Gross Profit* ~ income minus all costs, including capital costs.
- *Gross Value added* ~ contribution to gross national product (GNP). Income minus all expenses except capital costs and crew cost.
- *Fleet size and composition and value*
- *Return to be shared* - (share of owner (incl. vessel) and crew after paying the running costs) Turnover - landings costs – fuel costs – food costs – bait costs – ice costs (can be calculated from DCF data)

It is important to identify which indicators are appropriate for the specific cases being assessed as it is unlikely that all of these will be available or appropriate in all cases. The scoping meeting should identify specific economic criteria to allow a comparison between different plans. Once economic criteria for evaluation are selected, the appropriate methodology and data should be specified. The scoping meeting should identify additional data and models that might be required to evaluate the effects of the plan.

Longer term economic indicators over the period of the impact assessment should be obtained from cost benefit analysis.

- Net present value

Social indicators

- *Employment (and in other fishery sectors)*

- *Salary ~ if data is available (in the future) to compare with other sectors (job market)*

7. COST EFFECTIVENESS OF CONTROL AND ENFORCEMENT

Do the different options have important differences in implementation costs against their effectiveness in delivering the objectives of the plan. (for example is one option able to deliver better conservation measures than another at comparable costs, or do both options have similar conservation properties with differing costs). There is currently no general methodology to provide a quantitative cost/benefit analysis of control and enforcement, however, if there are important aspects to be considered these should be described qualitatively.

8. CONCLUSIONS TO THE IMPACT ASSESSMENT

8.1. Comparison of Options

- based on agreed criteria and draw-up a short-list of options that satisfy the Commissions Objectives for further discussion (Always include option « No Change»)
- Provide a summary table of options
- Screen possible options to see which can best meet the objectives using the agreed criteria from the scoping meeting to be used to compare the options.

8.2. Effectiveness: best placed to achieve the objectives (select appropriately just to relate to the objectives given above)

- What would be the short and long term impacts for the stock(s) and fleets and linked economic sectors affected by the different options. Will the tactical objectives of the plan be achieved?
- What would be the short and long term impacts of the multi-annual plan on the environment and the ecosystem, for example by-catch, discards, non-target species?
- Are there any likely side effects that might result from the plan? (for example, changes in behaviour that affect other fisheries, or environmental consequences, changes in the market).
- Has the implementation been affected by external factors such as global change, ecosystems effects, or other fisheries?

8.3. Efficiency: cost-effectiveness

- What will be the impact of this plan in terms of for example employment, gross revenue of the fleet?

- Will there be any effects on the broader industry (processing, transporting, auxiliary)?
- What are the expected economic benefit/loss during the period of implementation?

8.4. Consistency: limiting trade-offs across the economic, social and environmental domains

- Are there important tradeoffs between the three main objectives of the CFP (economic, social and environment) that are importantly different amongst the options.
- Are is there any overriding major imbalances among the three main objectives of sustainable economic, social and environmental aspects.

8.5. Forward look to Evaluation

- Define a set of appropriate indicators to measure implementation, compliance, effectiveness, costs and other impacts.
- Plan for future evaluation or review of the policy initiative (when, by whom, what, how?)

Notes:-

- 1) Achieving targets (F_{msy})— means with 50% probability of achieving this by specified time
- 2) Precautionary approach criteria in agreement with ICES criteria (95% $SSB > B_{lim}$) (95% $F < F_{lim}$)

ANNEX B BIOLOGICAL MANAGEMENT STRATEGY EVALUATION OF THE MULTI-ANNUAL MANAGEMENT PLAN FOR NORTH SEA SOLE AND PLAICE

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1. INTRODUCTION

This working document presents the results of a management strategy evaluation (MSE) of the multi-annual plan for sole and plaice in the North Sea (European Commission Council Regulation (EC) No 676/2007). Full results of impacts on the fishery and the stocks are presented. The evaluation also aims to see if the multi-annual plan constitutes a precautionary approach to the management of the two stocks. The evaluation includes tests of the robustness of the plan to uncertainty by evaluating its implementation across a range of plausible scenarios of starting conditions, stock dynamics and mixed fishery dynamics. In addition to applying the harvest control rules (HCRs) as specified currently in the plan, a number of potential tactical options are explored to identify if the performance of the plan can be improved. A full feedback MSE approach is applied, but there is no economic component incorporated within the feedback.

2. EVALUATION METHODOLOGY

The MSE is a full feedback stochastic projection model in which observations from the ‘true’ simulated populations of sole and plaice are used in assessment models (XSA) to produce a ‘perceived’ view of the stocks. There are uncertainties/error in observations from the true population (catch and indices of abundance) included in the process. These are modelled by assuming random noise for the landings, discards and surveys, based on historical estimates of uncertainty. The biological dynamics include random variability in recruitment and weights at age (resampled from the recent period). In addition to the biology, the fisheries system is modelled with simple fleet dynamic rules for three different fleets targeting the two species.

The analyses were carried out using the FLR package (FLCore v3.0; Kell et al. 2007), a collection of data types and methods written in the R language (v2.8.1; R Development Core Team 2008) as part of the EU EFIMAS-COMMIT-FISBOAT project cluster. All code, data and additional sources for checking, validating and evaluation are freely available upon request.

2.1. Simulation model formulation

2.1.1. *Biological operating model*

The biological operating model consists of age structured population models of the ‘real’ plaice and sole stocks in the North Sea. The models are conditioned to reflect our current understanding of the states and dynamics of the two stocks. The results presented here are based on two WGNSSK 2010 assessments: the XSA model (Darby and Flatman 1994) and SCA model (Aarts and Poos 2009) for sole and plaice stocks in the North Sea, utilising data up to and including 2008 values.

The simulation was initiated in 2003. The stock numbers at age in the initial year were taken from the assessment results (ICES WGNSSK, 2010). Landings, discards and survivors of the two stocks were calculated for the years up to 2009 given the model estimated (natural & fishing) mortality rates for the period 2003 to 2010. Recruits up to 2010 were also taken from the assessments results. From 2011 onwards fishing mortality is determined by the multiannual plan and the simulation continues with recruits estimated from the stock-recruitment relationship, given the stock sizes, with random noise added that corresponds to the observed residual variation over the last 25 years.

The historic numbers at age (starting point) and the future stock-recruit relationship are considered to be the primary sources of biological error in the evaluation. There is no variation in future weights at age (mean of the last five years), maturity ogives (knife edge values as used in the assessments of the stocks) or natural mortality (a value of 0.1 for all ages and years for both stocks).

2.1.2. *Fleet dynamics and the fishery*

A simplified fleet structure is considered due to data constraints. While the fleet structure is a simplification, it is believed that this structure is adequate for the purposes of the evaluation. To parameterize the model, specifically to estimate selectivity at age and catchability (relating effort to F) both total effort and catch at age data are needed on a fleet level. Using the data available (from 2003-2008) three fleet components are considered: Dutch 80mm beam trawl, BT1 100mm beam trawl (plaice only), and Other. The effects of the fishery on the two stocks is modeled as the combined effect of these three different fishing fleets. This allows for a distinction between OTB (fishing almost exclusively plaice) and TBB (fishing both species) gears. The Dutch fleet is modeled separate from the other two fleets because it has a very high proportion of the North Sea sole and plaice landings (WGNSSK 2010), as well as being a data-rich component of the fishery.

The fleet operating model affects the number at age in the two fish stocks via the fishing mortality rate (F) per year. Conversion from numbers to weights is done using the individual weights at age. These weights are different for the individuals in the population, and between landings and discards, because of differences in the size selectivity of the gear and the discarding process. Fishing mortality rate for each age group is calculated as the product of fishing effort (f), catchability (q) and selectivity. This simplistically implies a linear relationship between fishing mortality and fleet effort for each species. The historic selectivity-at-age (Figure 2.1) and catchability were estimated from the Fishbase dataset that holds all landings at age for the different international fleets, the international discards data, and the demersal assessment working group stock assessment results. The latter include estimates of fishing mortality by year and age. The total fishing mortalities can be used to create partial fishing mortalities by age and year for the different fleet segments using the discards-at-age and landings-at-age data.

In plaice, a substantial proportion of the catches are discarded, especially for the younger ages that are caught but fall below the minimum landing size. This was dealt with in the simulations by calculating separate discards and landings selectivities and catchabilities for each fleet targeting plaice. This resulted in a simulated dataset with ‘real’ landings values for the two species and discard values for the plaice stock used in fitting the assessment model (XSA) during each year of the simulations.

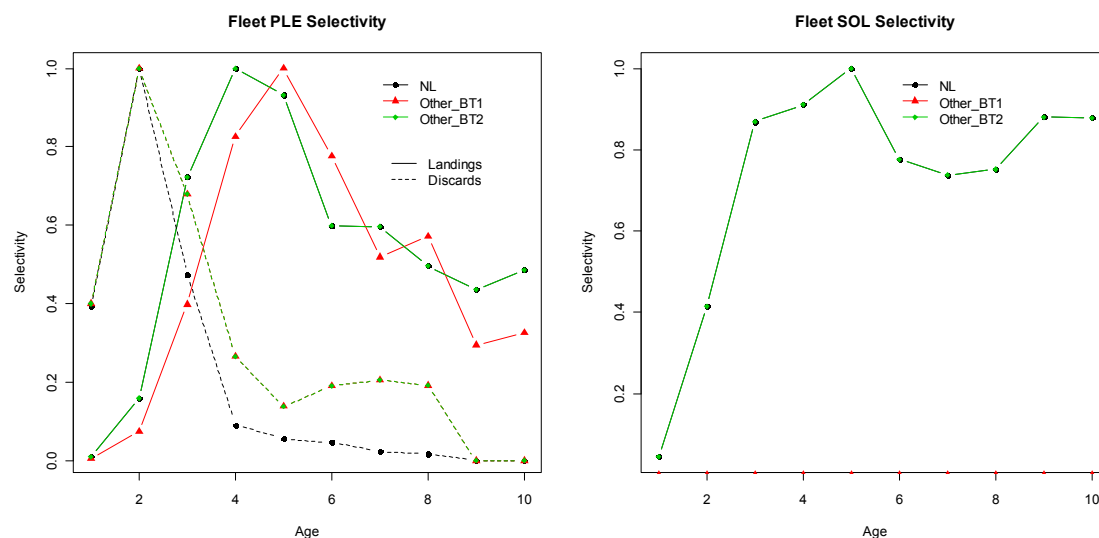


Figure 2.1. The selectivities by age (relative to the maximally selected age) of each species by the three fleets used in the MSE simulations.

Possible increase of efficiency of the fleets over time has been taken into account in the current model in the form of technological creep percentages (Rijnsdorp et al., 2006). Estimates of partial fishing mortality rate for sole and plaice were found to increase annually by 2.8% (sole) and 1.6% (plaice) in the recent period. The positive trend was considered to be due to an increase in skipper skills and investment in auxiliary equipment, the replacement of old vessels by new ones and, to a lesser extent, to upgrade engines. These values were used to incrementally increase the catchability of sole and plaice over the simulated period. There are no trend changes in selectivity through time, future selectivity is based on the mean recent historic values (5 years).

Most of the scenarios evaluated assume that the fleets will fish up both TACs while avoiding catching overquota fish. In other words, no implementation error is assumed in this scenario. The evaluation tests the multiannual plan as if it will be implemented as specified. Given that this is an evaluation of the plan and that none of the

articles contained within the plan include any strange or novel concepts that would require special enforcement measures, it seems reasonable to consider any deviations from the application of the plan in reality can not be considered to be a result of the plan itself. However, a set of scenarios considering mixed fishery behaviour were run to test the significance of this assumption.

2.1.3. Assessment and forecast

In order to set a management measure for year y , assessment data will be available up to year $y-2$ and the assessment itself is carried out in year $y-1$. The stock assessment process results in fishing mortalities estimates until year $y-2$ and survivor estimates and SSB estimates (at the first of January) until year $y-1$. A deterministic short-term forecast procedure then calculates the TAC for year y , based on assumptions about F and recruitment in the year $y-1$ and y . The assessment output and short-term forecast data might deviate from the real population characteristics as modeled in the biological operating model part because of the introduction of process error, model error, estimation error and observation errors.

The information or perception on the stocks status is generated through the explicit inclusion of a stock assessment in the simulation. Catches, discards and landings of the fleets are “recorded” in the model. Mimicking the assessment procedures, three surveys sample the plaice stock, and two surveys sample the sole stock by fishing with a constant and low fishing effort. Catches per unit of effort are assumed to be linearly related to stock abundance, thus result in two survey indices on the state of the stocks. The implementation of the XSA stock assessment in simulations for use in the multiannual plan HCR means that the MSE explicitly takes into account the impact of error generated by the stock assessment process.

To simulate observation error, the assessment input data were generated from the “real” population with error coefficients. Variance estimates for observations by age (Table 2.1) were used to generate log-normal error. The error coefficients for the simulated survey catches are generated from the catchability residuals at age for each survey as estimated by the WGNSSK stock assessment. The error coefficients on the landings and discards are generated from the standard errors estimated by the SCA assessments for sole and plaice. Biological parameters of the stocks in the assessment process are assumed to be equal to the biological parameters set in the operating model.

Table 2.1 Variances associated with the generation of observation errors for the catch (landings and discards) and survey indices for use in the annual assessments of the two stocks in the simulation model (observation error component of the simulation).

	Plaice					Sole				
	Catch		Surveys			Catch		Surveys		
Age	Lan	Dis	BTS- Isis	BTS- Tridens	SNS	Lan	Dis	BTS- ISIS	SNS	NL Trawl Beam
1	1.31	0.2	0.22	1.33	0.23	2.13	-	0.06	0.07	-
2	0.25	0.1	0.18	0.38	0.55	0.12	-	0.22	0.29	0.09
3	0.03	0.18	0.2	0.08	0.92	0.02	-	0.31	0.2	0.03
4	0.01	0.24	0.11	0.08	-	0.02	-	0.17	0.43	0.04
5	0.01	0.68	0.28	0.1	-	0.02	-	0.49	-	0.05
6	0.01	0.9	0.32	0.08	-	0.01	-	0.48	-	0.06
7	0.01	1.9	0.39	0.1	-	0.04	-	0.39	-	0.06

8	0.02	8.69	0.75	0.13	-	0.06	-	0.49	-	0.16
9	0.08	-	-	0.1	-	0.2	-	0.39	-	0.05
10	0.08	-	-	-	-	0.2	-	-	-	-
Min	0.01	0.1	0.11	0.08	0.23	0.01	-	0.06	0.07	0.03
Max	1.31	8.69	0.75	1.33	0.92	2.13	-	0.49	0.43	0.16
Mean	0.18	1.61	0.31	0.26	0.57	0.28	-	0.33	0.25	0.07

2.2. The management regulation

The European Commission Council Regulation (EC) No 676/2007 is attached in full in Appendix A. The adopted plan is the main instrument for flatfish fishery management in the North Sea, and was developed with the intention to also contribute to the recovery of other stocks such as cod. In drawing up the multiannual plan, the European Council tried to take into account the fact that the high fishing mortality rate for plaice is to a great extent due to the large discards from beam-trawl sole fishing with 80mm nets in the southern North Sea. The North Sea plaice and sole stocks are currently managed by TACs, days at sea restrictions and technical measures. The stocks are exploited by several fisheries but most of the catch is taken by the mixed beam trawl fisheries. The control of the fishing mortality rates envisaged in the plan is to be achieved by establishing an appropriate method for setting the level of total allowable catches (TACs) of the stocks, and limitations on permissible fishing effort.

The objectives of the first stage of the agreement are to bring the two stocks to within safe biological limits. For plaice, these safe biological limits are a fishing mortality below 0.6 and an estimated spawning biomass exceeding 230 000 ton. For sole the safe biological limits are a fishing mortality below 0.4 and spawning biomass exceeding 35 000 ton. TACs applied will correspond with fishing mortality that will be reduced by 10% year-on-year until the target levels have been reached, while annual variations in TACs will be kept within 15%. According to Article 5 of the Regulation the Council will amend the agreed plan when the stocks of plaice and sole have returned to within safe biological limits for two years in succession. The council shall decide on the basis of a review proposal from the European Commission that will permit the exploitation of the stocks at a fishing mortality rate compatible with maximum sustainable yield. The proposal for review shall be accompanied by a full impact assessment that takes into account the opinion of the North Sea Regional Advisory Council.

Advice on long term management from ICES indicates that at low target fishing mortalities, low risk to reproduction and high long term yields are achieved simultaneously. In other words there is no conflict between the two main objectives of the multiannual plan. A low fishing mortality will lead simultaneously to high yield and a low risk to reproduction (lower than the 5-10% risk which has generally been considered acceptable by managers).

The management measures were implemented within the models following all of the specifications of the multiannual plan as closely as possible. However, some of the articles in the plan can only be implemented in a simulation with some interpretation, simply because they are not specified sufficiently to be dealt with in mathematical rules. One example of this is article 18 in the plan, where both the SSB level below which additional TAC reductions shall be taken is not specified, nor is the magnitude of the additional TAC reductions.

2.2.1. Simulation of the multiannual plan management measures

Both output and input management measures are included within the plan. The output measures, described in Chapter II (Articles 6-8), consist of setting TACs for each stock based on fishing mortality objectives (annual reductions in F and target F_s for each stock). The input measures, described in Chapter III (Article 9), are

implemented as effort reductions in which the change in effort (days at sea) is proportional to the fishing effort required to land the TACs. In addition to these specified management measures there is also a Special Circumstances clause (Chapter V, Article 18) that allows for a greater reduction in TAC/effort should the SSB of either stock be found to be suffering from reduced reproductive capacity.

In the management part of the model, the perceived fishing mortality (F) from the XSA assessments and the target reference points specified in the multiannual plan are used as inputs to the harvest control rule (HCR). The HCR formulates the advice for setting the TACs according to the intended fishing mortality. The HCR also defines the allowable fishing effort for the fleets based on the F required to land the TAC or effort restrictions that need to be applied when the target F value has not yet been achieved.

Each year the total effort to be applied by the ‘real’ fishery is calculated as the *maximum* of the amounts needed to land the full TAC of each species (based on the ‘real’ population and the relationship between F and effort). The overquota landings of the species that required less effort to take the total catch are ignored i.e. landings beyond the TAC are not removed from the population (except in the case of mixed fishery scenarios). Total effort may be reduced if the HCR sets an upper limit on the total allowable effort (e.g. if F remains above F_{tar} , reduce allowable effort by 10%, or the percentage required to get F down to the target value, whichever is lowest), which would obviously reduce overquota and may lead to the TACs not being fully caught. The total effort is converted to F for each species.

For article 18 in the plan, the limit reference points were used to determine whether the stocks suffer from ‘reduced reproductive capacity’. A 25% TAC reduction would result if they were.

2.3. Output results

A number of standard biological and fishery indicators will be retained from the simulations to analyse the outcomes. These are divided into fishery and stock metrics. In addition to these some indicators will be examined to account for the need to move towards good ecological status (GES) by 2020. Specifically, the proportion of the population larger than the mean length at first maturation will be examined. Other population structure metrics useful for assessing progress in terms of GES could include metrics on the population structure (mean age, age diversity) and the discards proportion in the fishery (for plaice).

For all metrics means and percentile values (median, 5-95, 10-90 and 25-75) will be calculated for each year of the projections. The first ten iterations of the stochastic runs will also be retained to illustrate individual run trajectories of SSB, catch and recruitment.

The metrics will be evaluated at the following specific years and time horizons:

- 2015 (target year for fmsy)
- 2025 (final year of the long term evaluation)
- 2011-2015 (short-term performance)
- 2016-2025 (ten year long-term period)

Plots will be produced of time series of metrics showing median values and 90% confidence limits. ‘Worm plots’ of the first ten iterations of the stochastic simulations will be produced as well as box plots (median, interquartile range and 90% confidence limits) of the metric values at 2015, 2025 and the averages over the short-term and long-term.

2.3.1. *Effects on the fishery*

Metrics examined include:

- Mean F
- Yield (total catch, landings and discards)
- Catch/TAC variability, including the number and amount of negative changes in TAC vs. positive changes in TAC.
- Inter annual change based on Average % change from year to year of parameters.

2.3.2. *Effects on the stock*

Metrics examined include:

- SSB
- Recruitment
- $SSB > B_{pa}$ and $F < F_{pa}$ (safe biological status) as % of stocks and years
- Precautionary risk

2.3.2.1. Precautionary criteria

In order to show that the management plan is precautionary for the two species under consideration according to ICES, we use the Criteria agreed during WKOMSE to be applied in the evaluation of Harvest Control Rules/Management Plans in relation to precautionary reference points (Table 2.2). Results were examined to 2015 and beyond and the risk will be evaluated over the ten year period 2011-2020.

Table 2.2. Precautionary criteria agreed during WKOMSE for evaluating multiannual plans (ICES 2010a)

Element	Criterion	Notes
Time frame	2015: The performance of the HCR (MP) will be evaluated using as time horizon the year 2015 (in agreement with the Johannesburg Declaration)	The simulations will use as starting year the population parameter estimates from the most recent assessment (e.g. from WG or benchmark).
Biological Reference Points	Limit reference points: Evaluate the HCR (MP) based on B_{lim} and F_{lim}	If new limit reference points have been accepted (ACOM) these should be used in the evaluation; In the absence of defined limit reference points such as B_{lim} , use proxies (e.g. x_{lim} derived from %SPR, or 0.5Bmsy, or 20%B ₀ ,)
Risk	5%: The HCR (MP) is considered to be precautionary if the probability of $SSB < B_{lim}$ (or $x < x_{lim}$) is less than 5%	Criteria for <u>management plan of stocks within safe biological limits</u> to be precautionary: no more than 5% of 10 year simulation runs having one or more years outside of safe biological limits. Criteria for <u>recovery plan</u> qualifying as precautionary: at least 95% of simulation runs recovering by 2015 (the year WSSD committed for rebuilding fish stocks).

		The 5% will be used unless managers specify another percentage.
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Precautionary references points have been defined for the two stocks: Bpa, Blim, Fpa and Flim (plaice only). A precautionary management plan is defined by in terms of risk of $SSB < Blim$. Safe biological status is defined as $SSB > Bpa$ and $F < Fpa$, as specified in the management plan. In addition to this, the current target values and new estimates of Fmsy will be considered. No MSY Btrigger reference point has been defined for either stock.

According to WKOMSE (ICES 2010a), in order for the management plan to be considered precautionary (in terms of Blim), it is necessary that:

“...no more than 5% of 10 year simulation runs having one or more years outside of safe biological limits.”

This will be evaluated over three ten years periods: short term (2011-2020), post-2015 term (2016-2025) and medium term term (2021-2030).

2.4. Options evaluated

Several scenarios of the underlying stock dynamics (biological options) are tested as a sensitivity analysis of the implementation uncertainty (Table 2.2). In addition, a number of potential revisions to the HCRs contained within the plan are examined (tactical options, Table 2.3). For each scenario, 100 stochastic simulations will run out to 2025 in some cases, 2030 in others.

2.4.1. Biological options

Biological scenarios were tested to determine whether or not the results of the evaluation were sensitive to the assumptions of initial starting condition and underlying stock productivity (stock recruit function). All biological scenarios were run assuming that the multi-annual plan would be applied in its current form. If the results are robust to these uncertainties, then management options can be analysed based on the results from the base case underlying biology. In addition to these alternative stock assumptions, an ‘worst case’ recruitment scenario was also conducted to specifically evaluate what would happen in the unlikely event of stock collapse due to repeated low levels of recruitment.

2.4.1.1. B1 – Base Case

The base case biological model for both stocks in the simulations comes from the most recent accepted ICES assessment (XSA model fits) of the stock. The latest assessment from June 2010 (WGNSSK, 2010) is used. Starting numbers are taken from the model fits. Recruitment is generated using the estimated model fits and uncertainty for segmented regression (hockey stick) and Ricker stock recruit functions from the Bayesian analysis presented in Annex C of this report. Each iteration uses one of the two stock recruit functions, with the total proportions of these two according to the likelihood of fits (see Annex C for a full description).

2.4.1.2. B2 – Starting points

Past retrospective patterns suggest that this starting point may be uncertain. Therefore, to test the sensitivity of the multi-annual plan performance to the stock status in the starting point, three alternative starting points based on an alternative statistical catch at age (SCA) model are used. These are the model fits corresponding to the 5th, 50th (median) and 95th percentiles of the uncertainty estimates of SSB in the final year, hence providing a range of potential stock statuses at the start of the simulations (Note: the starting point for these scenarios is 2009 because the most recent SCA model fits were not available). Recruitment is generated using a segmented regression curve as Bayesian model fits have not been calculated for these data.

Table 2.2. Biological scenarios evaluated in the management strategy evaluation of the North Sea plaice and sole multi-annual plan.

Scenario Set	Scenario	<u>Simulation Settings</u>		<u>Biology Settings</u>		<u>Management Settings</u>				
		# Iterations	Final Year	Starting Point	Stock-Recruit Function	Ftar PLE	Ftar SOL	TAC Change limit	F Red.	Effort Limit.
B1	BC_Bayes	100	2030	XSA	Bayes	0.3	0.2	0.15	0.1	NA
B2 ¹	AltSP_SCA_05	100	2025	SCA 5 th ile	segreg	0.3	0.2	0.15	0.1	NA
	AltSP_SCA_50	100	2025	SCA median	segreg	0.3	0.2	0.15	0.1	NA
	AltSP_SCA_95	100	2025	SCA 95 th ile	segreg	0.3	0.2	0.15	0.1	NA
	segreg	100	2025	XSA	segreg	0.3	0.2	0.15	0.1	NA
B3 ¹	ricker	100	2025	XSA	ricker	0.3	0.2	0.15	0.1	NA
	bevholt	100	2025	XSA	bevholt	0.3	0.2	0.15	0.1	NA
	AltSr_L	100	2025	XSA	GeoMean Low	0.3	0.2	0.15	0.1	NA
B4 ¹	AltSr_M	100	2025	XSA	GeoMean Mid	0.3	0.2	0.15	0.1	NA
	AltSr_H	100	2025	XSA	GeoMean High	0.3	0.2	0.15	0.1	NA
B5	tarCrash_Recov	100	2030	XSA	Minimum/segreg	0.3	0.2	0.15	0.1	NA
	tarCrash_Recov_25chng	100	2030	XSA	Minimum/segreg	0.3	0.2	0.25	0.1	NA
B6	Both_Eff	100	2030	XSA	segreg	0.3	0.2	0.15	0.1	None
	Least_Eff	100	2030	XSA	segreg	0.3	0.2	0.15	0.1	Least
	MostSol_Eff	100	2030	XSA	segreg	0.3	0.2	0.15	0.1	Min(Sole,Most)

¹=Incorrect Bayes proportions in base case comparison run

Table 2.3. Management scenarios evaluated in the management strategy evaluation of the North Sea plaice and sole multi-annual plan.

Scenario Set	Scenario	<u>Simulation Settings</u>		<u>Biology Settings</u>		<u>Management Settings</u>			
		# Iterations	Final Year	Starting Point	Stock-Recruit Function	Ftar_PLE	Ftar_SOL	TAC Change limit	F reduction
M1 ¹	HCR_Ftar	100	2025	XSA	segreg	0.25	0.35	0.15	0.1
	HCR_TACchnng	100	2025	XSA	segreg	0.3	0.2	0.25	0.1
	HCR_Fred	100	2025	XSA	segreg	0.3	0.2	0.15	0.15
M2	Ftar_Bayes	21	2030	XSA	Bayes	0.23	0.35	0.15	0.1
	Ftar_15	21	2030	XSA	Bayes	0.15	0.15	0.15	0.1
	Ftar_25	21	2030	XSA	Bayes	0.25	0.25	0.15	0.1
	Ftar_rev	21	2030	XSA	Bayes	0.2	0.3	0.15	0.1
M3	Ftar_MSX	100	2030	XSA	Bayes	0.23	0.2	0.15	0.1
	Ftar_ICES	100	2030	XSA	Bayes	0.2	0.22	0.15	0.1
	Ftar_25	100	2030	XSA	Bayes	0.25	0.25	0.15	0.1

¹=Compared with segreg as a base case

2.4.1.3. B3 – Stock-recruitment functions

The spawning stock biomass (SBB), the biomass of the sexually mature part of the population, determines the number of recruits of the next year. Stock recruit relationships were examined over the full historic period with SSB and recruitment estimates from the XSA model (the SCA model estimates values over a shorter time period due to its reliance on survey indices). The Base line scenario includes both Ricker and hockey stick models with varying coefficients in order to include uncertainty in the S-R dynamics. Nevertheless, to evaluate the possibility of one form being dominant the relationships were selected individually for a set of scenarios. Given that neither of the stocks show any clear stock recruit relationship, three alternative functions were considered: segmented regression (hockey stick), Beverton and Holt and Ricker fits (Figure 2.2; Table 2.2 scenario set B3).

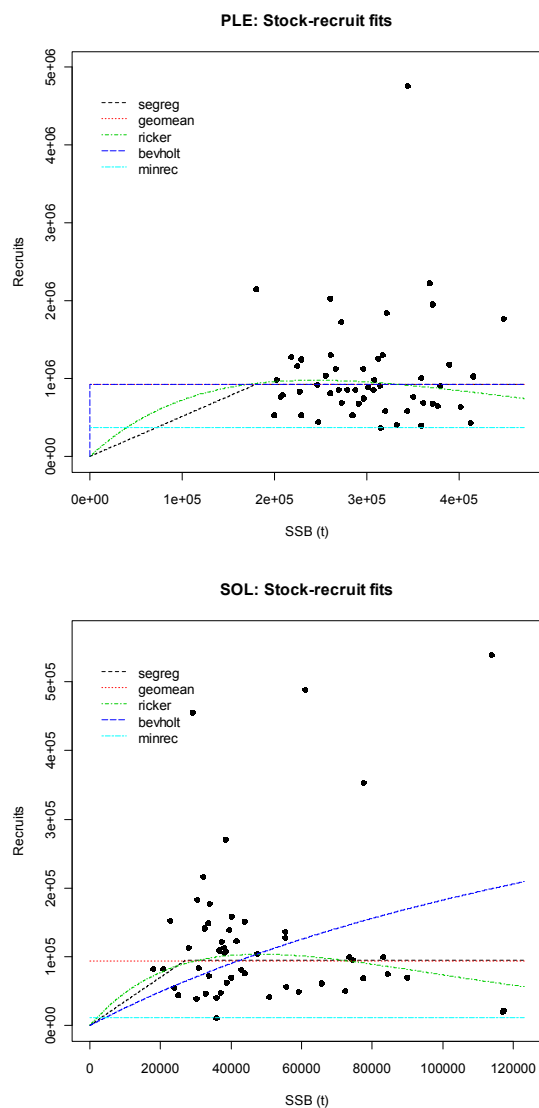


Figure 2.2. Stock-recruit function fits to the latest XSA assessment data for plaice and sole in the North Sea.

2.4.1.4. B4 – Recruitment regimes

In addition to alternative stock recruitment functions, the sensitivity to the relationship between stock size and recruitment was evaluated by using geometric mean recruitment from three different recruitment ‘regimes’ (low 1957-1972, mid 1994-present, and high 1973-1993; Table 2.2 scenario set B4).

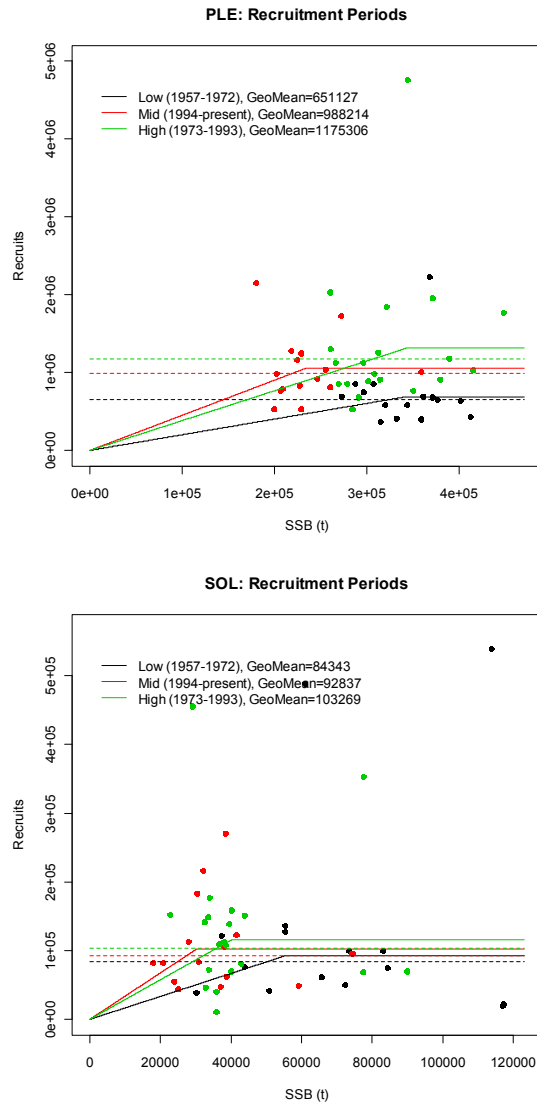


Figure 2.3. Geometric mean recruitment and segmented regression (hockey stick) curves fit to the data for three ‘recruitment regimes’ for plaice and sole in the North Sea.: low recruitment regime (1957-1972), mid recruitment regime (1994-present) and high recruitment regime (1973-1993).

2.4.1.5. B5 – ‘Worst case scenario’

Given that the plaice stock is currently considered to be in a very healthy state, it is useful to examine a scenario in which the stock falls into a less healthy state to see how the multi-annual plan is able to perform under these conditions. Once the F target had been met or passed, the scenario considered reduced recruitment to fluctuate around the minimum observed level over the entire time period until the stock reaches 75% of Blim before resuming the usual S-R function. This drives the stock to a very low level and then still has 2-3 very poor incoming year classes. It should be noted that such a catastrophic recruitment failure has never been observed for these stocks over the greater than 50 year time series. Hence probabilities of collapse should be considered as relative measures of the performance of candidate management options rather than possible likelihoods of risk to the stock.

2.4.1.6. B6 – Mixed Fishery

Most of the scenarios assume that the fleets will fish up both TACs while avoiding catching overquota fish. In other words, no implementation error is assumed in this scenario. This form of evaluation tests the multiannual plan as if it will be implemented as specified. Given that this is an evaluation of the plan and that none of the articles contained within the plan include any strange or novel concepts that would require special enforcement measures, it seems reasonable to consider any deviations from the application of the plan in reality can not be considered to be a result of the plan itself. However, it is worth considering the likely impacts of mixed fishery dynamics on the success of the multi-annual plan.

In order to examine the possible effect of the mixed fishery, three scenarios of fishing effort were examined in a further analysis. These scenarios cover a range of potential reactions to the TAC of one of the stocks being caught before the TAC for the other has been caught. In this case the fishery will either stop (*Least Eff*: i.e. the mixed fishery is limited by the least effort required), continue while avoiding catching the other by some technical or spatial changes in fleet behaviour (*Both Eff*: i.e. catches of stocks considered independent, both TACs caught) or continue to fish until the TAC of both stocks is caught, discarding the over quota catch caught for the other stock (*Most SOL Eff*: i.e. effort only limited by the most demanding TAC). Because sole is the main (most profitable) contribution to the landings, it is more likely that if sole is limiting (i.e. low TAC that can be caught with less effort) fishing for plaice only does not occur, simply because this would not be profitable. In the unlikely situation that there is a big discrepancy between the TACs, and plaice fishing would still be profitable, then plaice can be caught cleanly by spatial changes or technical restrictions. There are areas where plaice is present but not sole (e.g. further north in the North Sea). Also, changing gear used can prevent large overquota of sole while still landing plaice (e.g. shift from 80mm to 100mm mesh size). Considering these mitigating factors, the final scenario considers that fishing will continue until all sole is caught, but extra effort to catch plaice beyond this will not impact on the sole stock.

2.4.2. Tactical options

In the biological scenarios, the future management of the stocks strictly follows the rules in multiannual management plan. In this section a number of alternative tunings of the HCRs contained in the plan are considered. Alternative management scenarios looked at the likely impacts of varying aspects of the multi-annual plan on the stock and the fishery. These included different candidate F targets for each stock, increasing the allowable annual TAC change, and increasing the annual F reduction percentage. The results of these scenarios are presented in sections 3.2.1 – 3.2.3 and Tables 3.1 and 3.2.

2.4.2.1. M1 – HCR options

The main aspects of the HCRs contained within the plan are:

- target F values (currently 0.3 and 0.2 for plaice and sole, respectively)
- annual reductions in F until these targets are met (currently 10% steps)
- a limit on the permitted change in TAC (currently <15%)

In order to examine whether improvements can be made to the current plan, alternatives to the values provided in the current formulation will be evaluated. Initially the effect of changes on each of these three main aspects were examined, specifically:

- alternative target F values (similar to F_{msy} estimates from the Bayesian analysis)
- the potential of a greater annual decrease in F (15%) to increase the likelihood of achieving F_{msy} by 2015
- the effect of increasing the allowable changes in TAC (25%) to examine what size fluctuations would result and whether this would decrease the risk levels associated with the stocks.

2.4.2.2. M2 – Exploratory alternative F target range

Exploratory runs (only 21 replicates) were done to examine the potential range of F targets for each stock: 0.15 to 0.3 in steps of 0.05.

2.4.2.3. M3 – Alternative F targets

Following the exploratory F target runs three sets of potential targets were run. *Ftar_{MSY}* considers a plaice target of 0.23, corresponding to the value from the Bayesian analysis combining segmented regression and Ricker curves in proportions relative to the likelihood of model fits. For the sole stock, risk to the stock is a more important factor in determining long term F targets as currently estimated *F_{msy}* values are above what is considered to be safe for this stock (i.e. >5% risk of dropping below *B_{lim}*). Hence the sole target in this scenario was determined by examining the long term average ratio of *F_{PLE}*:*F_{SOL}* (Figure 2.4) and dividing the plaice target by this value. This comes out at an F target of 0.2 for sole, as is currently stipulated in the plan. The second scenario used, *Ftar_{ICES}*, the current ICES estimates for *F_{msy}* from the latest WGNSSK working group (0.2 and 0.22 for plaice and sole, respectively). Finally, *Ftar₂₅* uses an F target of 0.25 for both stocks.

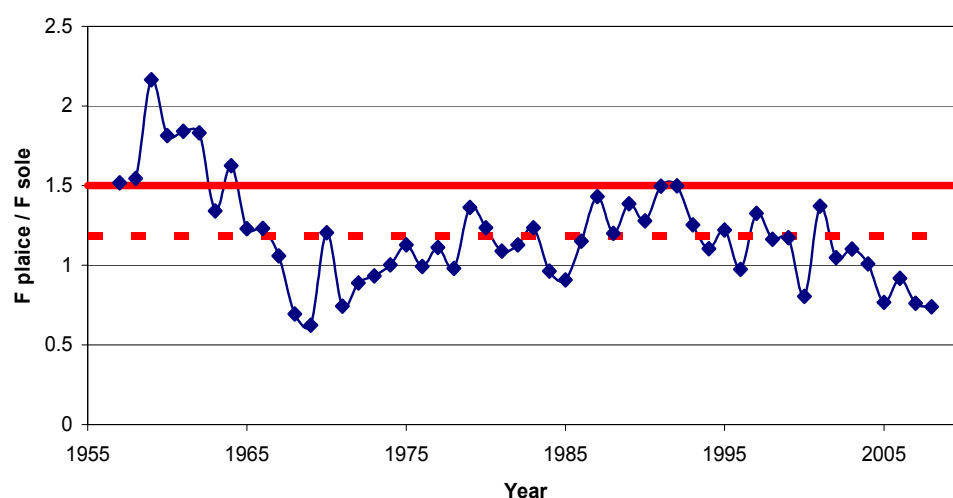


Figure 2.4. Time series of proportionality of sole and plaice fishing mortality (1957-2008), expressed as $F_{\text{plaice}}/F_{\text{sole}}$. The solid horizontal red line indicates the same proportionality in the target F values in the multi-annual plan (1.50), and the dashed horizontal red line indicates the mean value over the whole period (1.18).

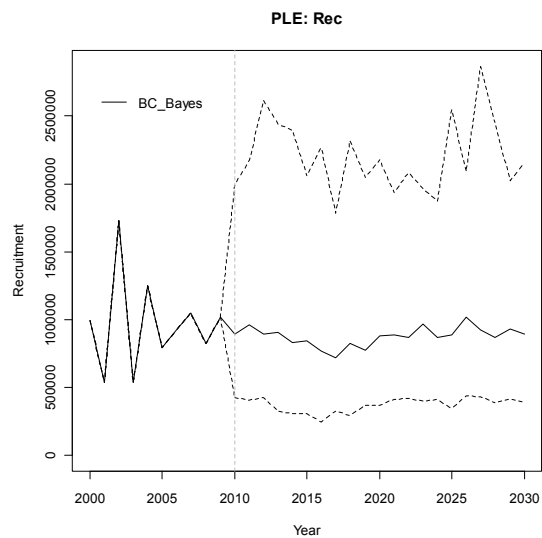
3. RESULTS

3.1. Biological options

3.1.1. B1 – Base Case

Under the base case scenario, (Table 2.2 option B1) both stocks show long term increase in both SSB and TAC (Figures 3.1 and 3.2). For plaice, the initial F is below the target level so the management is based on the target F straight away. This generally results in TAC increases limited by the maximum allowable TAC change for the first few years, and F only increases slowly towards the target level because of this constraint. As a result, the F reduction value used in the plan is seldom applied for plaice. For sole, the initial F is above the target level so management in the first few years applies the F reduction to reduce F towards the target value. The combination of increasing SSB and decreasing F lead to a more slowly increasing TAC for sole compared to plaice and as a result the TAC change limit is applied less frequently. The broad ranges in SSB, TAC and F are driven primarily by the variation in recruitment (large uncertainty around the stock recruit fits). Potential good environmental status (GES) indicators are shown in Figure 3.3 for plaice and sole. Both stocks see initial

increases in mean age and age diversity before this levels off somewhat as the stocks reach 'equilibrium' levels around the target F values. The discard proportion for plaice drops initially during the period when TAC increase is limited, but as F increases this proportion starts to increase slightly due to the accompanying increase in effort required to land the TAC.



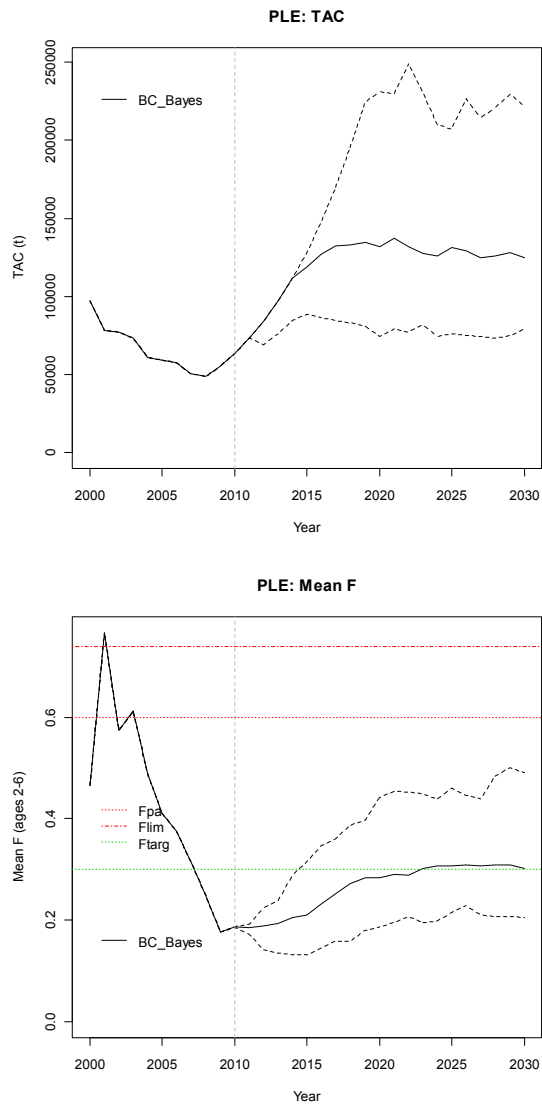


Figure 3.1. Plaice under the 'Base case' scenario (B1): time series of SSB (top left, with Blim and Bpa marked), recruitment (top right), TAC (bottom left) and mean fishing mortality for ages 2-6 (bottom right, with target F, Flim and Fpa marked). Time series comprise stock assessment results prior to 2010, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

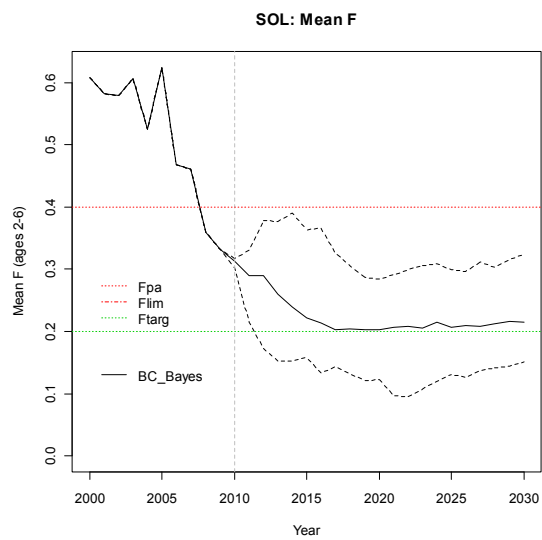
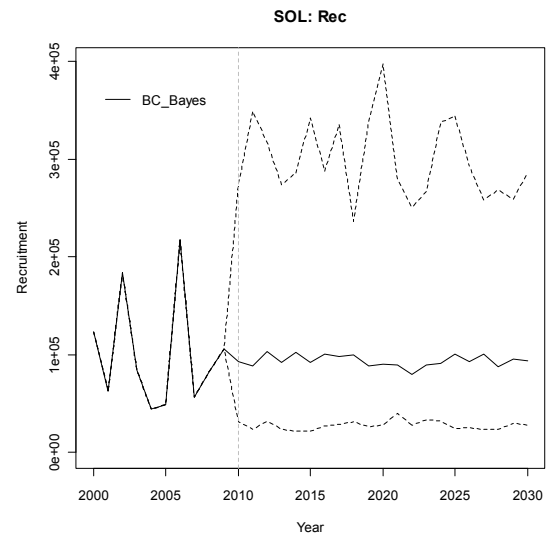


Figure 3.2. Sole under the ‘Base case’ scenario (B1): time series of SSB (top left, with Blim and Bpa marked), recruitment (top right), TAC (bottom left) and mean fishing mortality for ages 2-6 (bottom right, with target F, Flim and Fpa marked). Time series comprise stock assessment results prior to 2010, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

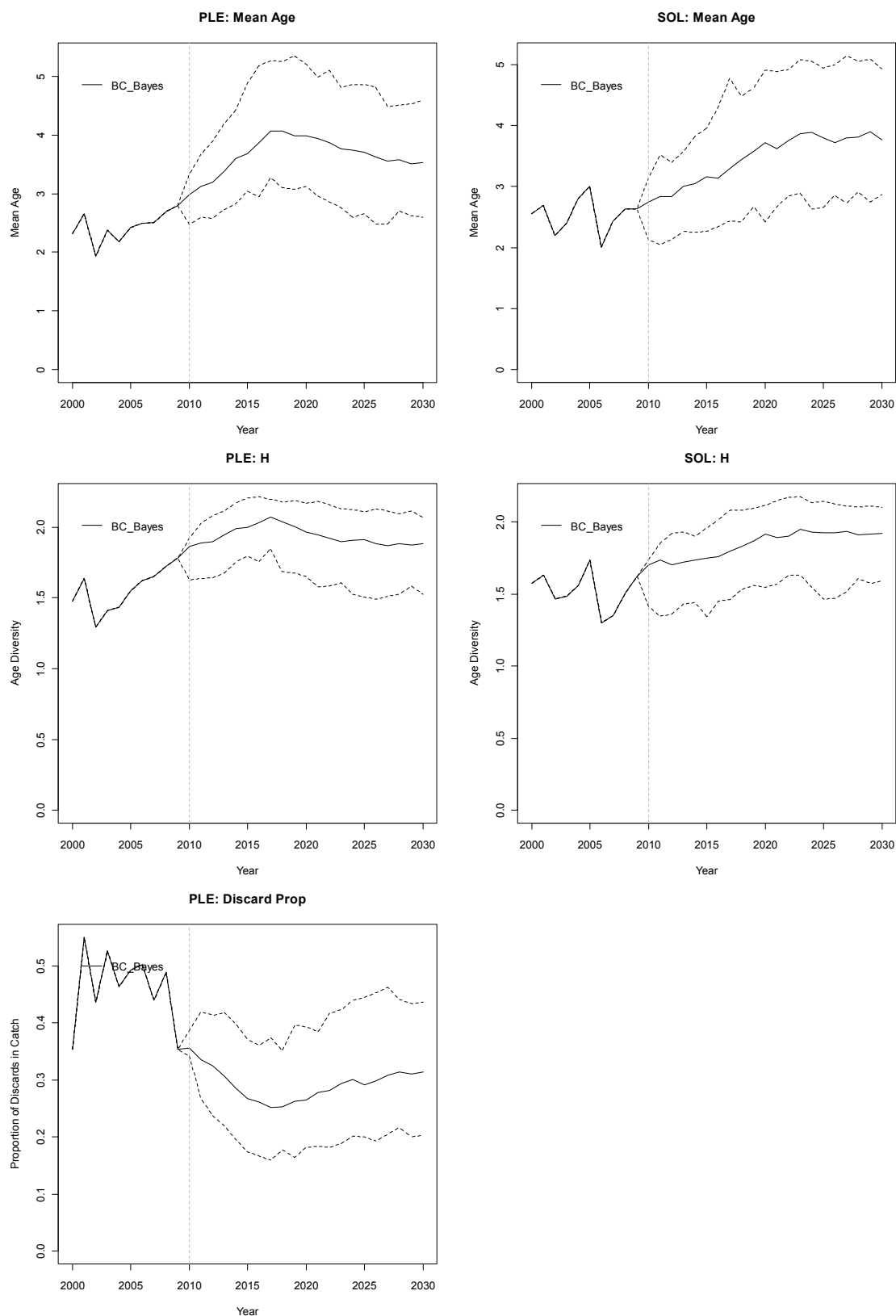


Figure 3.3. Indicators of good environmental status (GES) under the ‘Base case’ scenario (B1) for plaice (left) and sole (right): time series of mean age (top), age diversity (middle) and discards proportion in catch (bottom, plaice only). Time series comprise stock assessment results prior to 2010, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

3.1.2. B2 – Starting points

Both the rate of recovery (increase in SSB and decrease in F) as well as the pattern of recovery over time are very similar across the range of starting points for both stocks (Figures 3.4 and 3.5). The ‘poorer’ starting points show a greater degree of recovery at a slightly more rapid rate.

The alternative starting points for plaice (Table 2.2 option B2) do not appear to have a notable effect on the stock in the long term. Short term differences in TAC and SSB and the amount of time until the target F is reached do vary, but the trend of increasing stock size and TAC are the same in all cases, even for the poorest starting point (SCA 5th percentile). For sole, the XSA starting point (base case) represents the lowest initial stock size, though also a slightly lower F the 5th percentile of the SCA. The impact of starting point is the same as for plaice. Given these minor short term differences but coherence in the long term trends, and the fact that the base case for sole essentially is the poorest viable starting point, it is reasonable to use the XSA assessment values as the starting points for evaluating management option scenarios.

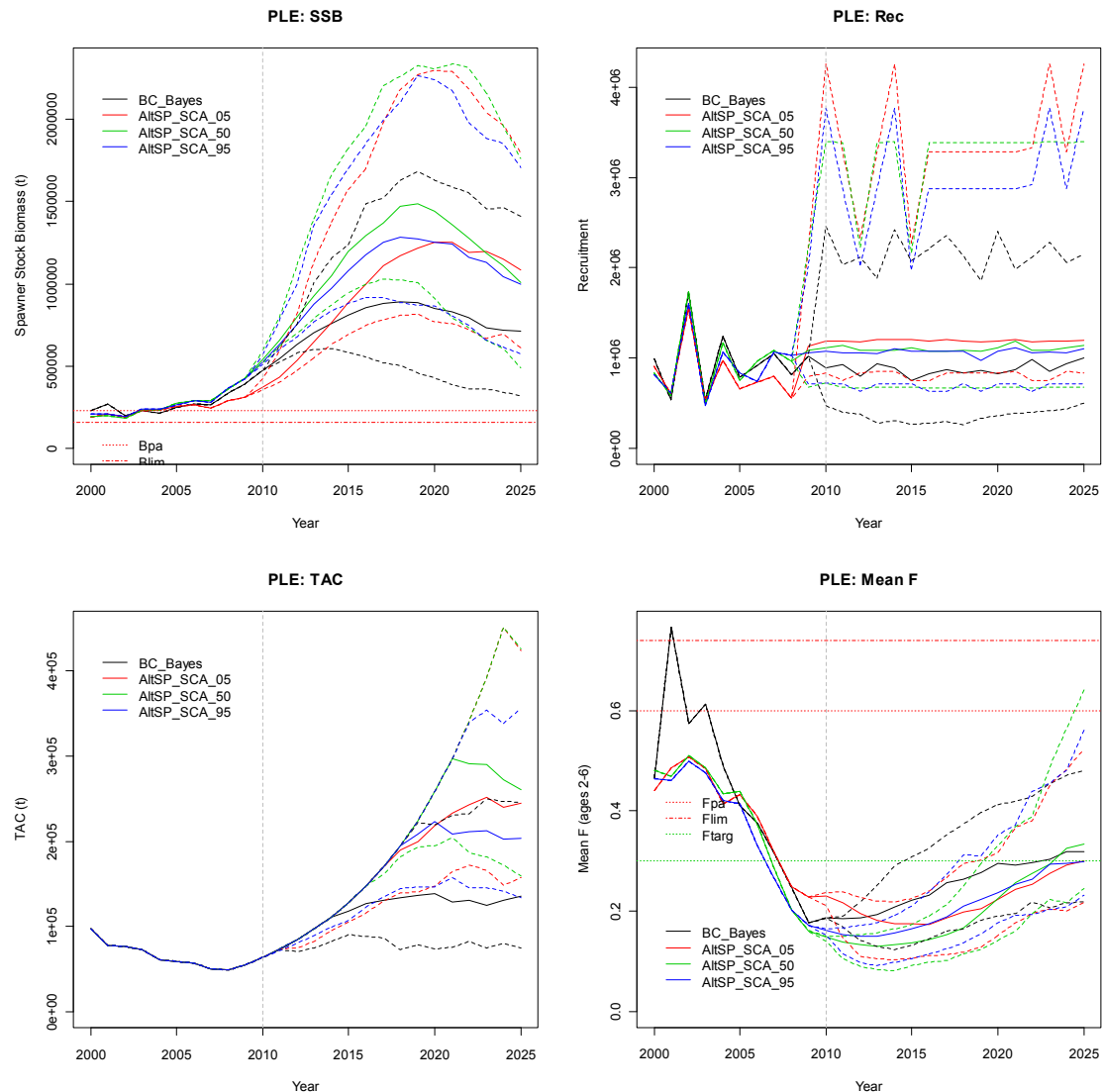
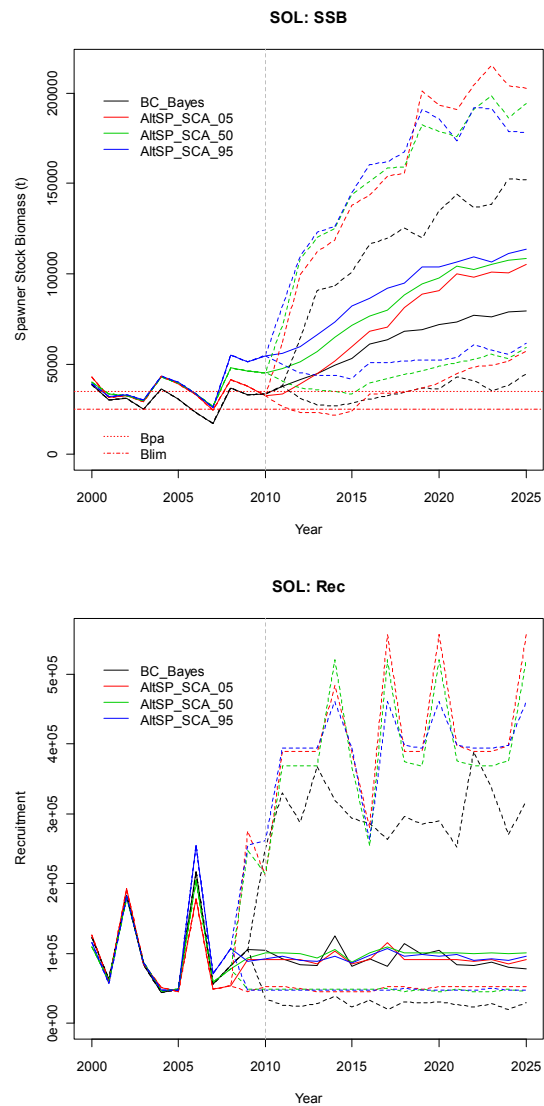


Figure 3.4. Plaice under the scenarios of alternative starting points (B2): time series of SSB (top left, with Blim and Bpa marked), recruitment (top right), TAC (bottom left) and mean fishing mortality for ages 2-6 (bottom right, with target F, Flim and Fpa marked). Time series comprise stock assessment results prior to 2010, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.



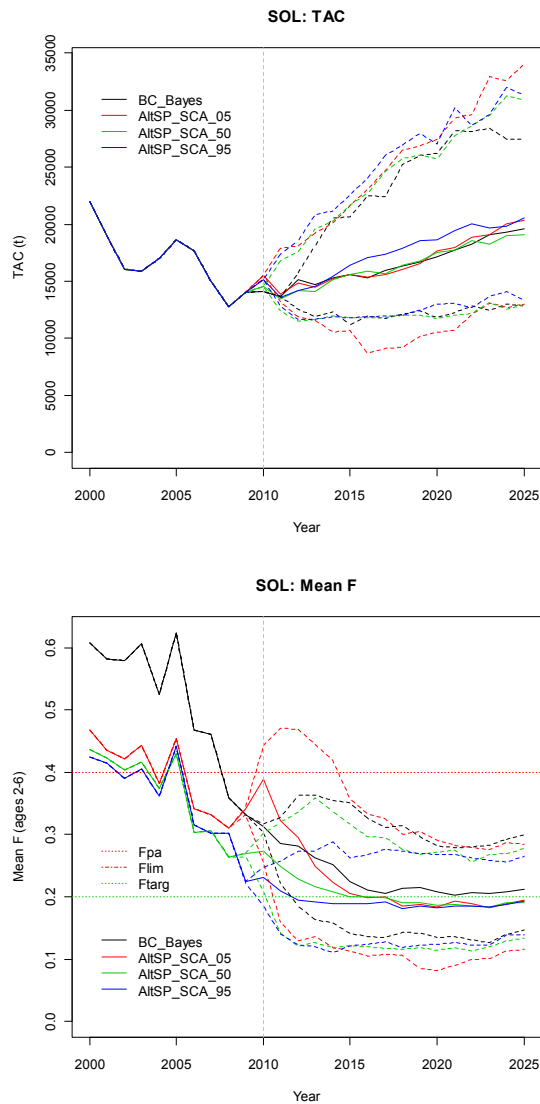
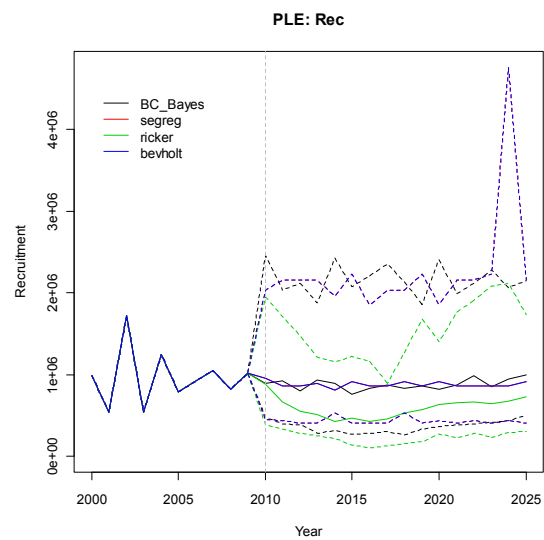
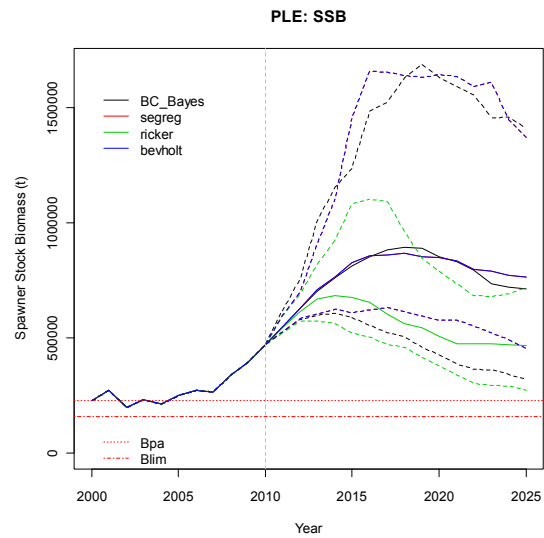


Figure 3.5. Sole under the scenarios of alternative starting points (B2): time series of SSB (top left, with Blim and Bpa marked), recruitment (top right), TAC (bottom left) and mean fishing mortality for ages 2-6 (bottom right, with target F, Flim and Fpa marked). Time series comprise stock assessment results prior to 2010, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

3.1.3. B3 – Stock-recruitment functions

Only the Ricker (plaice, Figure 3.6) and Beverton and Holt (sole, Figure 3.7) stock recruitment functions show any noticeable differences in stock and fishery developments compared to the base case scenario. The impact of this on future SSB and F values is as would be expected. In the case of plaice, as the stock reaches very high levels, the density dependence of the ricker function leads to reduced recruitment and the SSB stabilising at a lower level, as with the TAC. In the case of sole, the Ricker curve is flatter and the stock starts at a lower SSB, further away from the declining slope of the curve. As a result the reduction in recruitment as stock size increases is less evident for this stock. The Beverton and Holt curve has a higher maximum recruitment level than the base case, so as the stock grows larger, the accompanying increase in recruitment increases the potential for stock growth. This in turn leads to higher TACs and lower Fs. While potentially possible, the biological hypothesis behind the Ricker relationship is thought to be poorly supported for these flatfish stocks, and there is

a general lack of trend in the stock-recruit pairs. This supports the use of the Bayesian model fits and the use of stock recruit relationships in proportion to their estimated likelihoods.



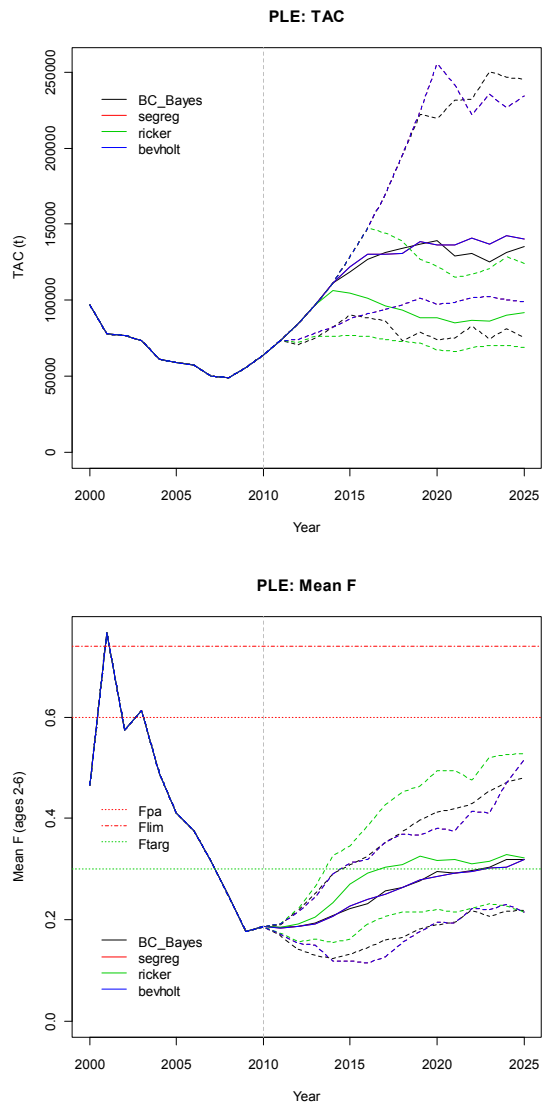
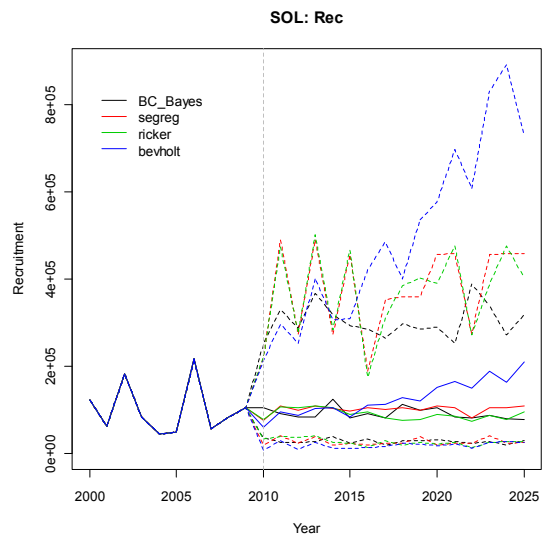
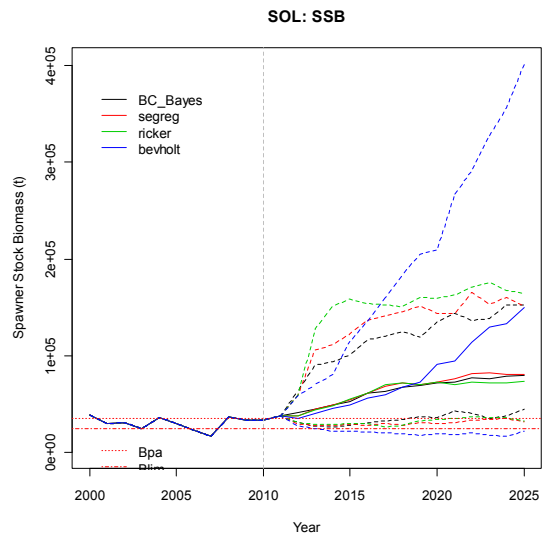


Figure 3.6. Plaice under the scenarios of alternative stock-recruit functions (B3): time series of SSB (top left, with Blim and Bpa marked), recruitment (top right), TAC (bottom left) and mean fishing mortality for ages 2-6 (bottom right, with target F, Flim and Fpa marked). Time series comprise stock assessment results prior to 2010, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.



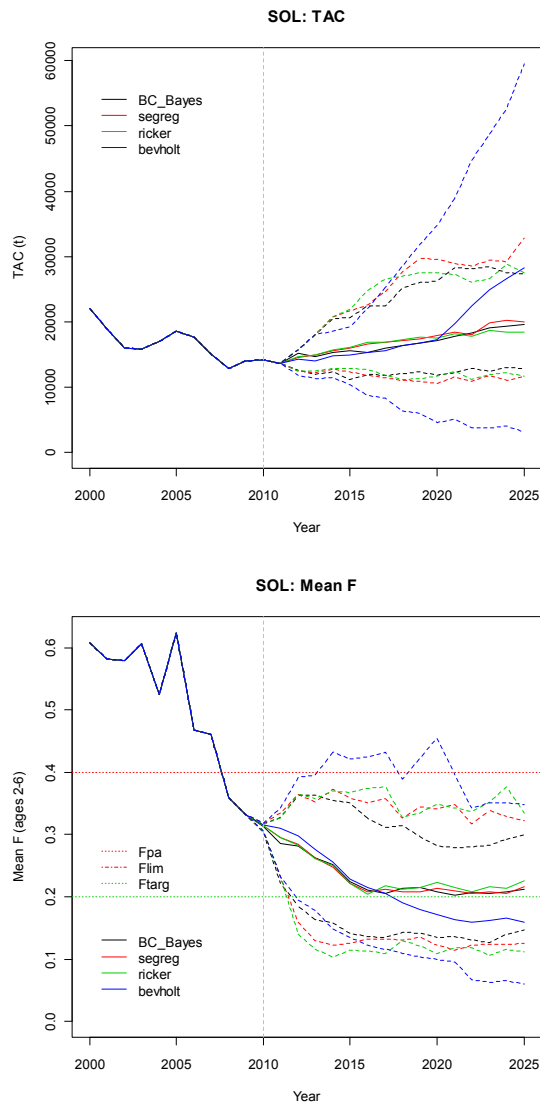
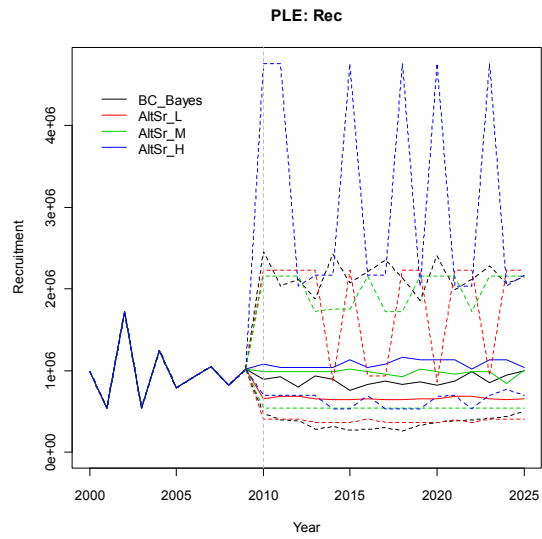
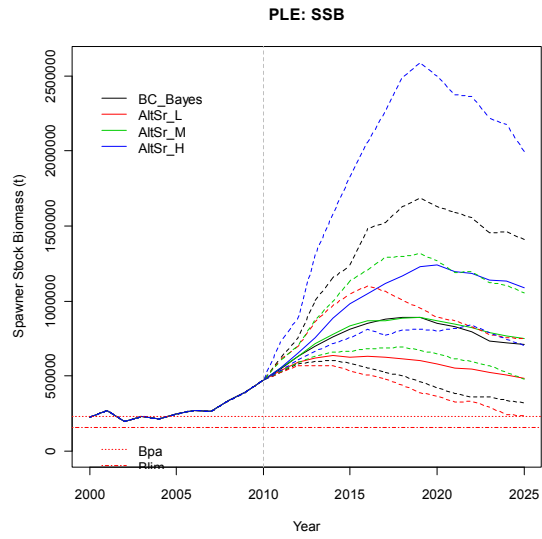


Figure 3.7. Sole under the scenarios of alternative stock-recruit functions (B3): time series of SSB (top left, with Blim and Bpa marked), recruitment (top right), TAC (bottom left) and mean fishing mortality for ages 2-6 (bottom right, with target F, Flim and Fpa marked). Time series comprise stock assessment results prior to 2010, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

3.1.4. B4 – Recruitment regimes

The differences in absolute level of recruitment between the three regimes are negligible for the sole stock, but are greater for the plaice stock. The impact of this is as expected, with long term stock size and TAC reduced under the low recruitment regime and increased in the high recruitment regime. However, the different levels of recruitment do not affect the trends in stock development and the multi-annual plan can still effectively keep the stock within safe biological limits under any of these recruitment regimes.



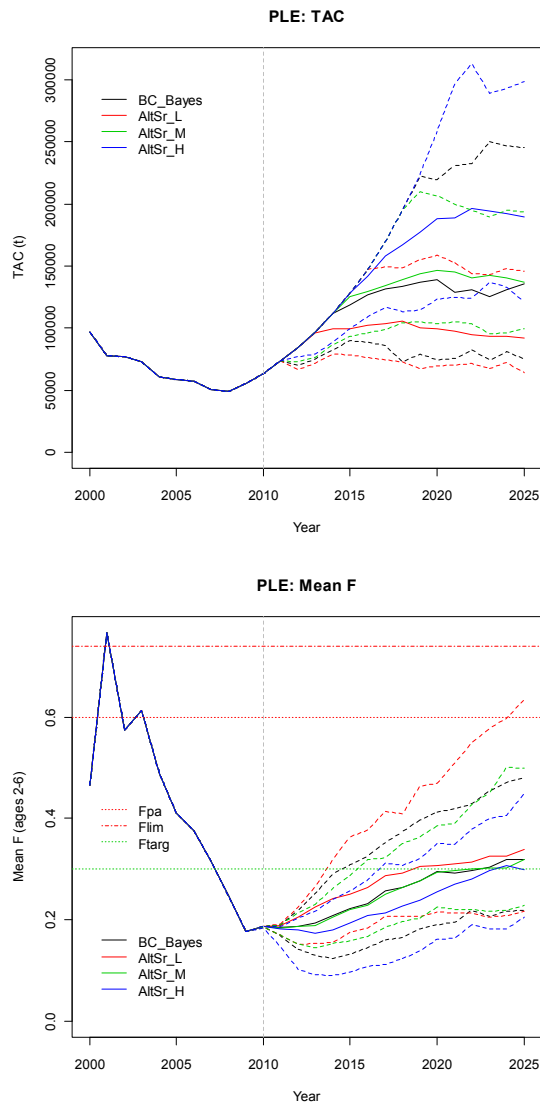
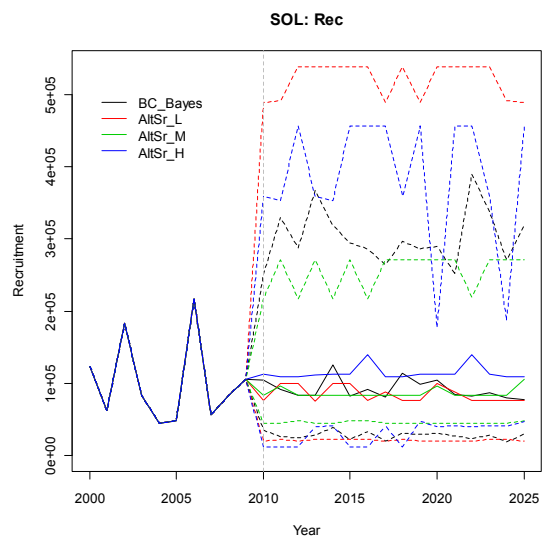
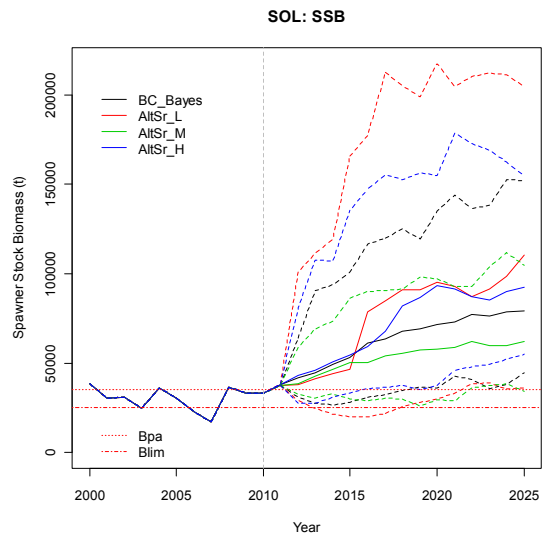


Figure 3.8. Placice under the scenarios of alternative recruitment regimes (B4): time series of SSB (top left, with Blim and Bpa marked), recruitment (top right), TAC (bottom left) and mean fishing mortality for ages 2-6 (bottom right, with target F, Flim and Fpa marked). Time series comprise stock assessment results prior to 2010, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.



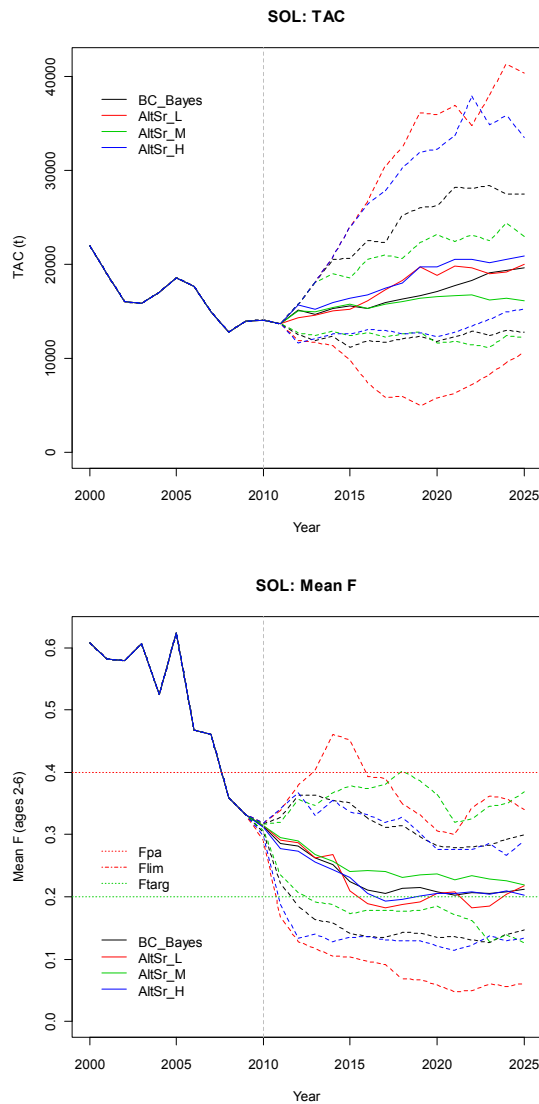


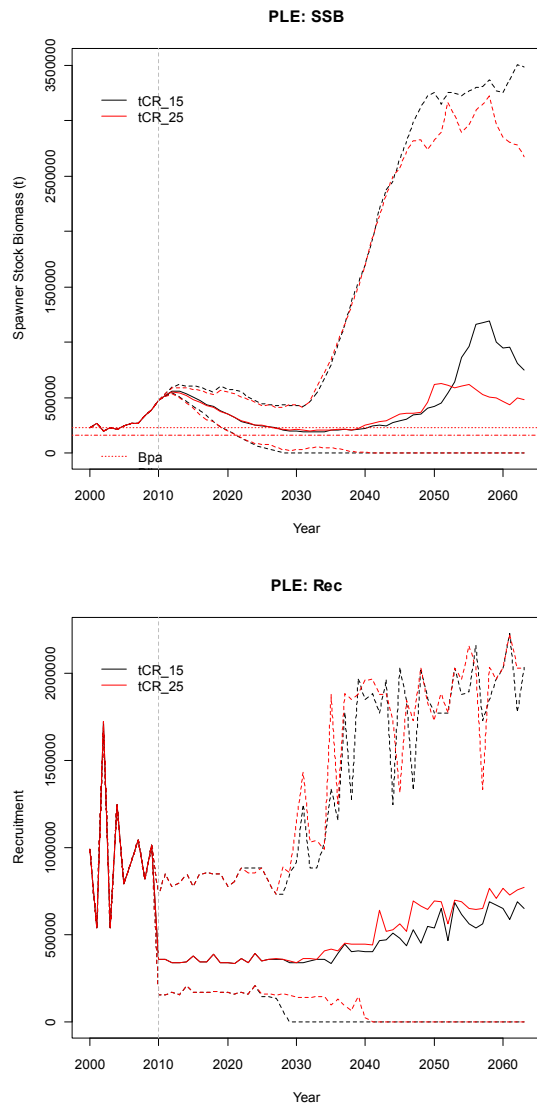
Figure 3.9. Sole under the scenarios of alternative recruitment regimes (B4): time series of SSB (top left, with Blim and Bpa marked), recruitment (top right), TAC (bottom left) and mean fishing mortality for ages 2-6 (bottom right, with target F, Flim and Fpa marked). Time series comprise stock assessment results prior to 2010, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

3.1.5. B5 – ‘Worst case scenario’

With the current healthy state of the plaice stock and low F, it takes about 20 years of minimum recruitment to drive plaice stock down to 75% of Blim (Figure 3.10). Once this has occurred, 17% of stocks collapse (though this is reduced to 13% if a 25% TAC change limit is allowed; Figure 3.12). Such a prolonged recruitment failure is unlikely and the high level of recovery from this very poor stock condition implies that the multi-annual plan can be considered robust to poor recruitment in short (given the strong status of stock) and long term. The length of the poor recruitment period required to drive the stock down to low levels would also for the management of the stock to react in order to avoid poor stock status.

The sole stock is more easily driven to low biomass levels (Figure 3.11). Target F is achieved in approximately 5 years and following this 5-10 years of minimum recruitment is required to reduce the stock below 75% of Blim. Thereafter most stocks collapse (65%; Figure 3.12). The likelihood of collapse reduces notably if 25% TAC

change limits are applied (39%), The multi-annual plan currently contains a clause allowing for more reactive management beyond the rules of the plan should the stock fall outside of safe biological limits (in relation to precautionary reference points). However, in the case of sole, this may be too late. Bpa is near to Blim and it has been observed in the past that the stock can change from above Bpa to below Blim in a single year. Fpa for this stock is also above the current management target so following the multi-annual plan HCR should keep the stock within safe biological limits with regards to F. However, in the case of a few poor year classes, using the precautionary reference points as a basis for reactive management may not be sufficient. It seems a greater ability to react to repeated poor incoming recruitment is required in the management plan, for example a recruitment reference level that a recent average can be compared with to trigger a greater reduction in TAC.



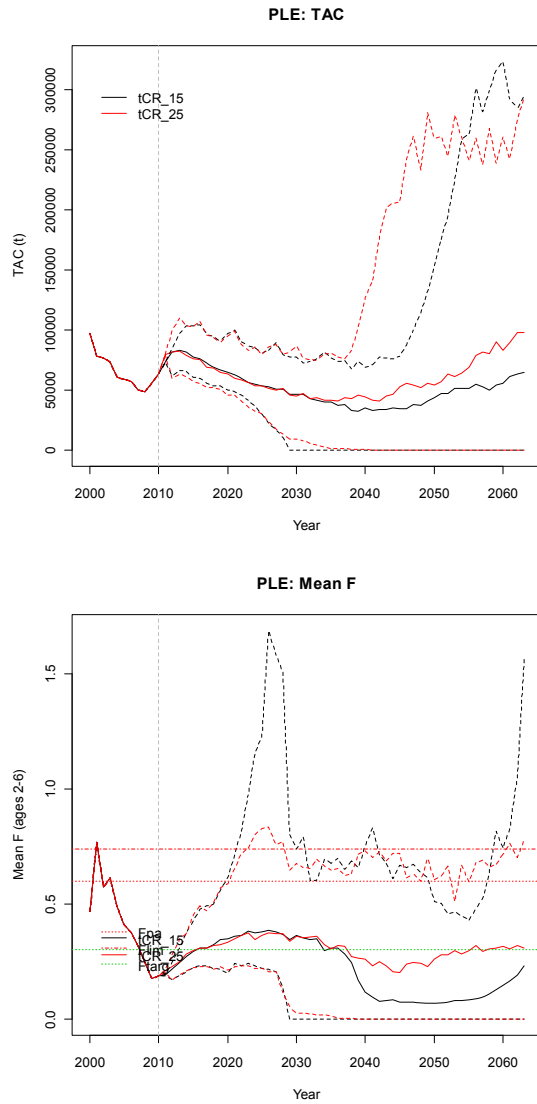
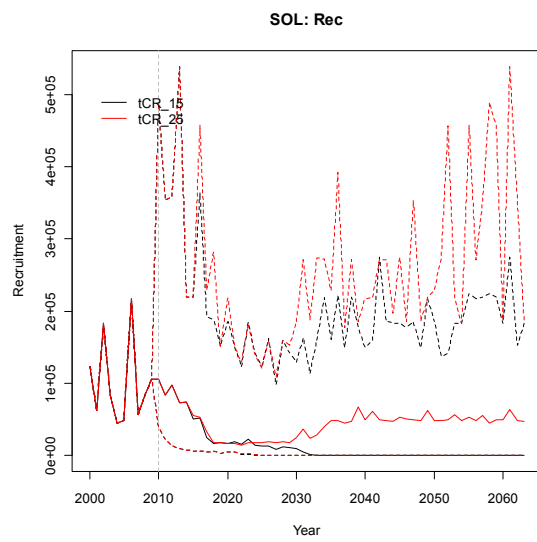
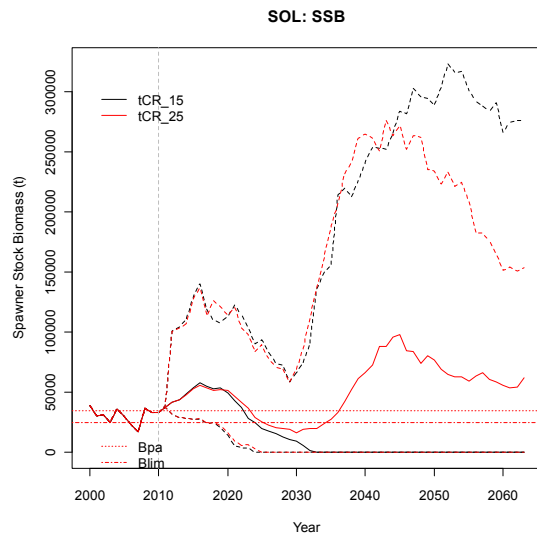


Figure 3.10. Plaice under the ‘worst case’ scenario (B5): time series of SSB (top left, with Blim and Bpa marked), recruitment (top right), TAC (bottom left) and mean fishing mortality for ages 2-6 (bottom right, with target F, Flim and Fpa marked). Time series comprise stock assessment results prior to 2010, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter. tCR_15 (black) = 15% TAC change limit, tCR_25 (red) = 25% TAC change limit.



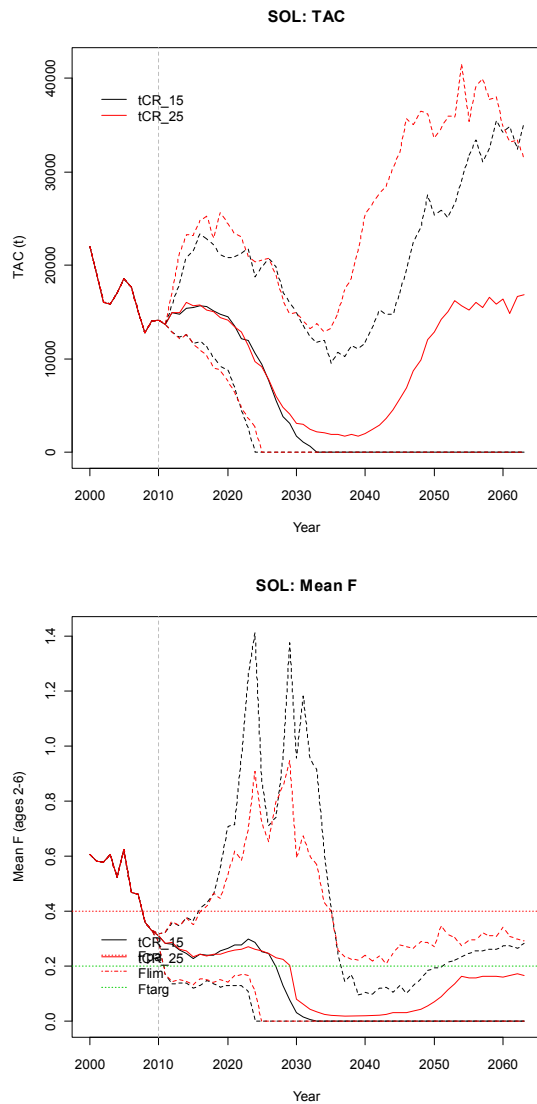


Figure 3.11. Sole under the 'worst case' scenario (B5): time series of SSB (top left, with Blim and Bpa marked), recruitment (top right), TAC (bottom left) and mean fishing mortality for ages 2-6 (bottom right, with target F, Flim and Fpa marked). Time series comprise stock assessment results prior to 2010, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter. tCR_15 (black) = 15% TAC change limit, tCR_25 (red) = 25% TAC change limit.

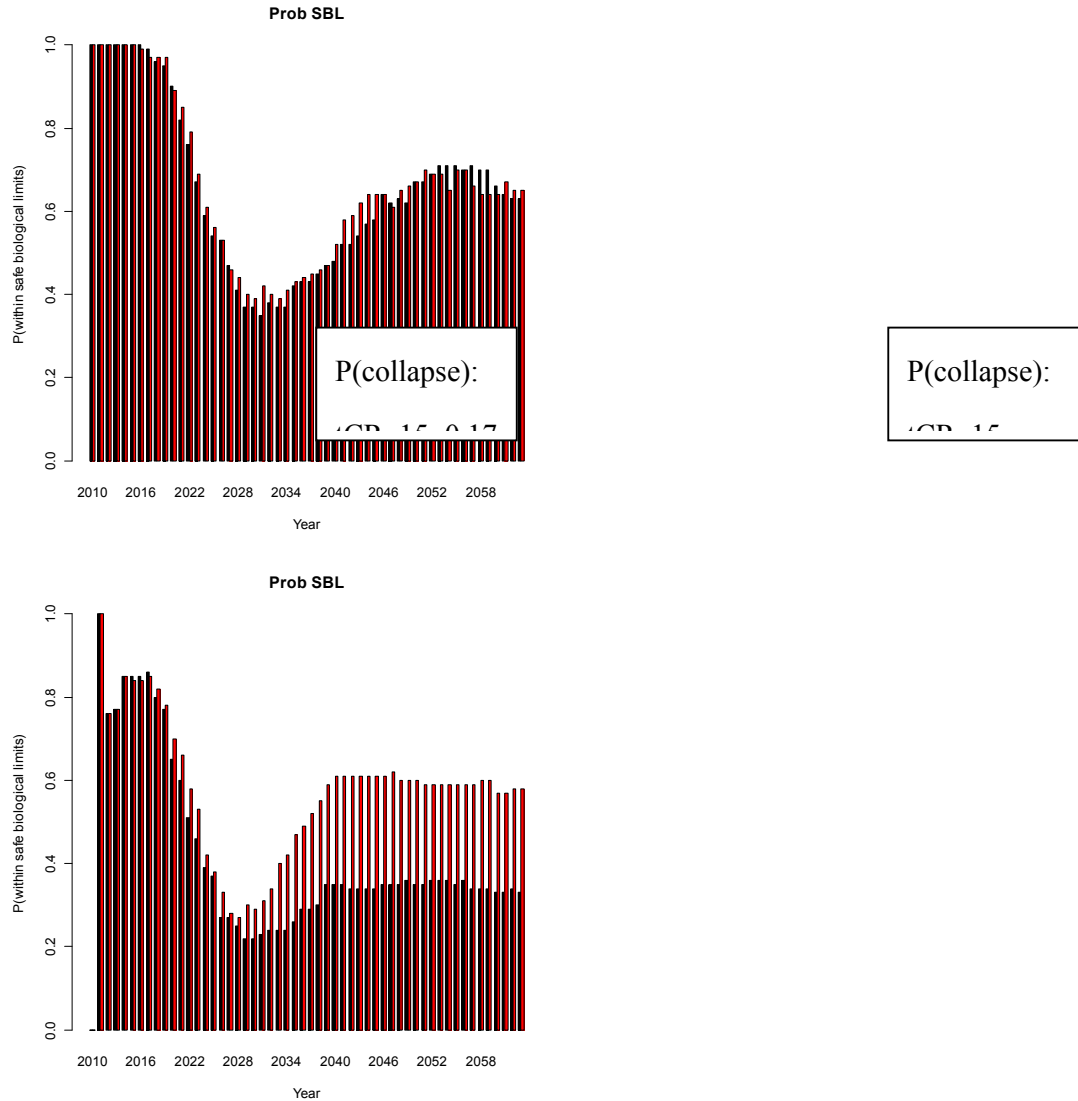


Figure 3.12. Probability of being within safe biological limits under the ‘worst case’ scenario (B1) for plaice (left) and sole (right). tCR_15 (black) = 15% TAC change limit, tCR_25 (red) = 25% TAC change limit.

3.1.6. B6 – Mixed fishery

3.1.6.1. Effects on the fishery

The trends of total effort by fleet, and the resultant F levels by stock, under the three mixed fishing scenarios are presented in Figure 3.13. The fishing effort for plaice and sole is identical under the *Least_Eff* and *MostSOL_Eff* scenarios, effort only differs in the *Both_Eff* scenario, where TACs are caught independently. Initially more effort is required to land the sole TAC than the plaice TAC but this reverses after as sole F decreases and plaice F increases according to the plan. If effort is limited in the plaice fishery, F remains at a low level, at or slightly above current F . If the plaice TAC is always caught, F increases slowly, the median level not reaching the target F before 2030. For sole, limiting effort allows for F to drop more rapidly to the target level, but in all cases the median F value reaches the target level by 2015. Thereafter F increases slowly, due to application error in setting TACS (i.e. imperfect perception of stock size and F when applying the HCR, and technical creep in the efficiency of the fleets).

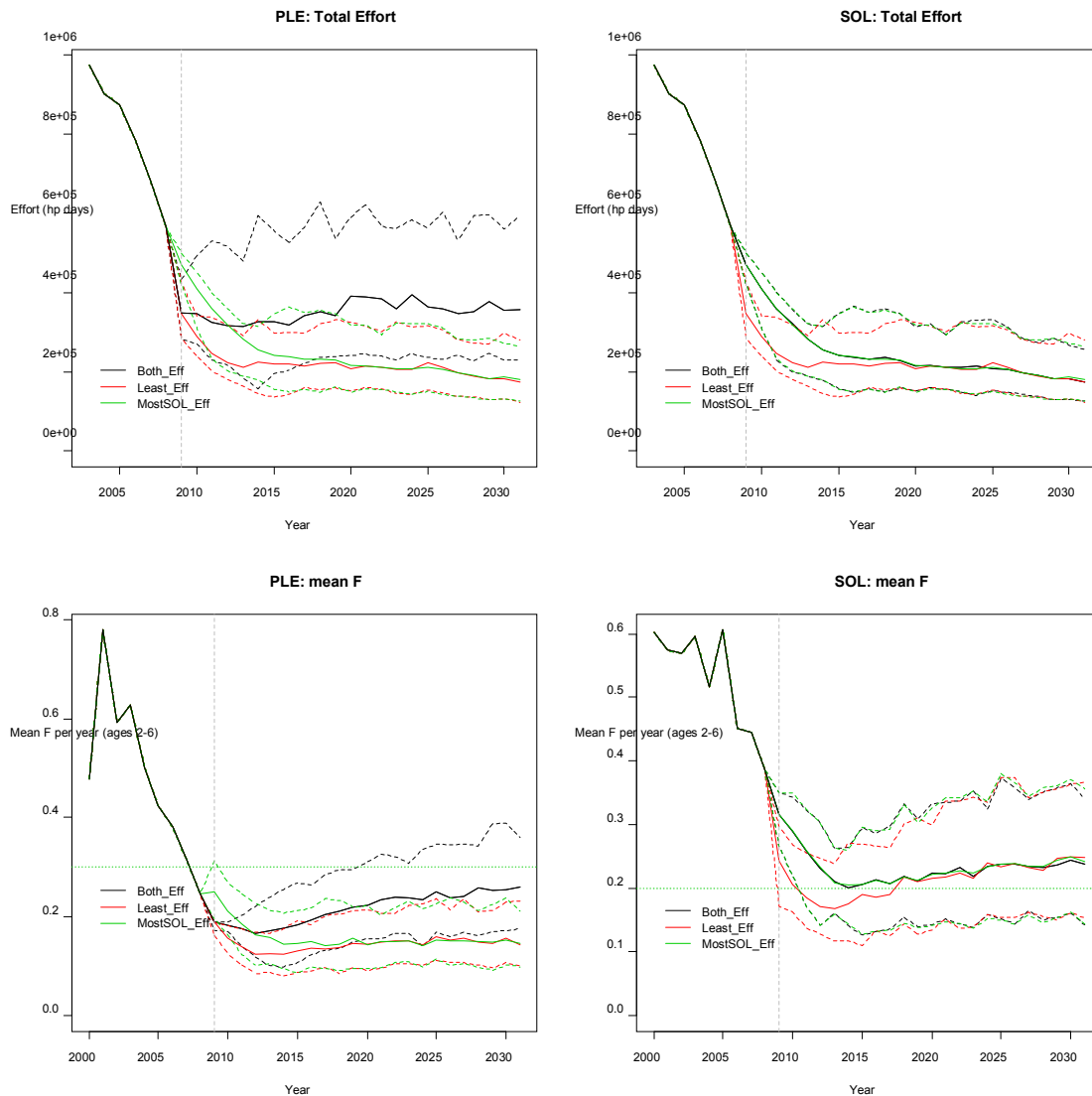


Figure 3.13. Total effort and resultant mean F values under the mixed fishery scenario (B6) for plaice (left) and sole (right). Time series comprise recorded values prior to 2009, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

Effort by fleet is presented in Figure 3.14. Patterns of change over time are similar for all three fleets, with a gradual decline following initial large declines prior to the simulation period. Only the *Other_BT1* fleet remains unaffected by sole effort restrictions (as this fleet catches only plaice due to large mesh size), but this fleet contributes very little to the overall catch. Landing the plaice TAC over the period examined require a gradual increase in effort by the BT2 fleets (NL and other) while landing the sole TAC require a gradual decrease. This follows naturally from the increase in F required for plaice (below the F target) and the decrease required for sole (above the F target).

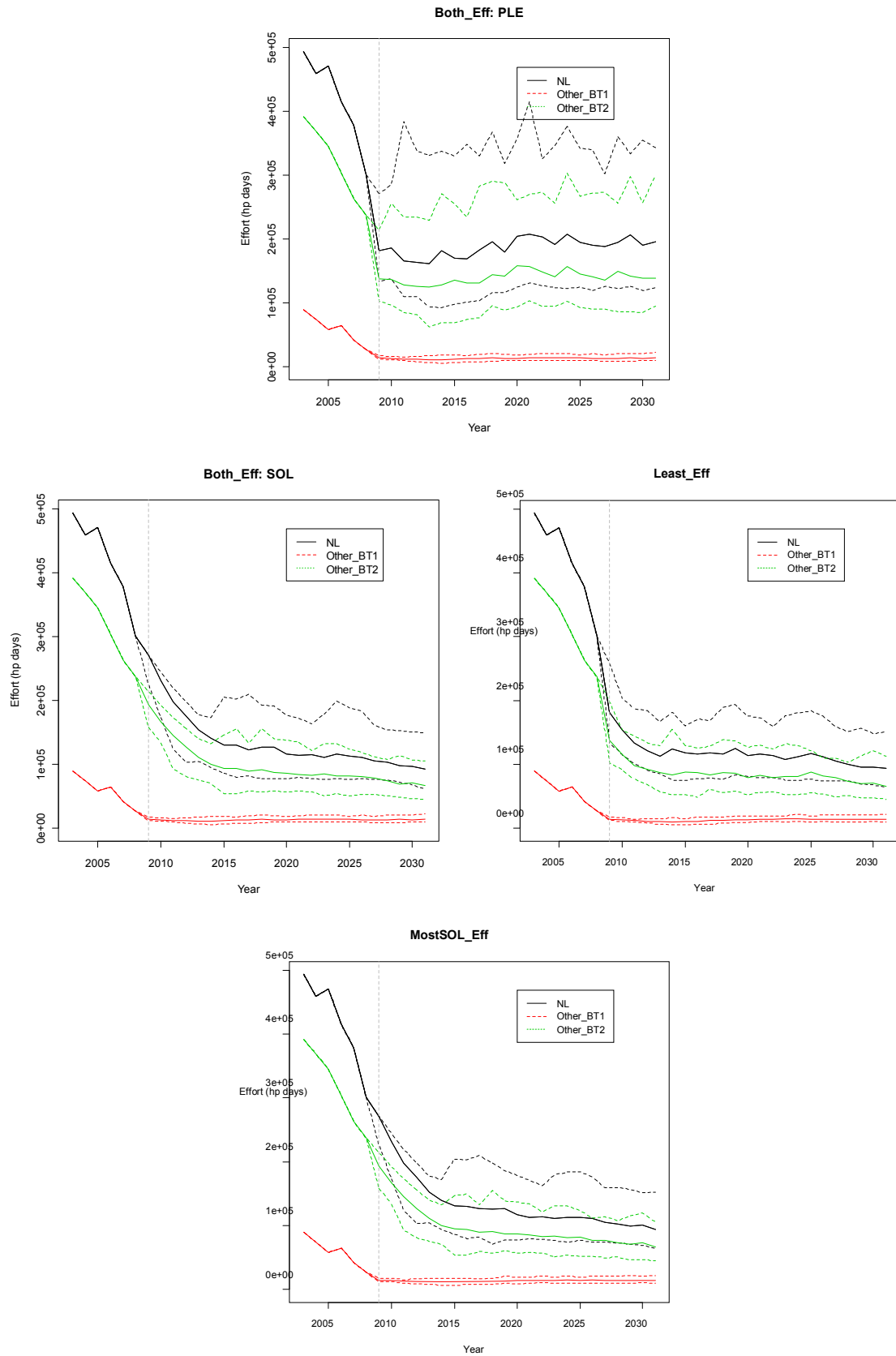
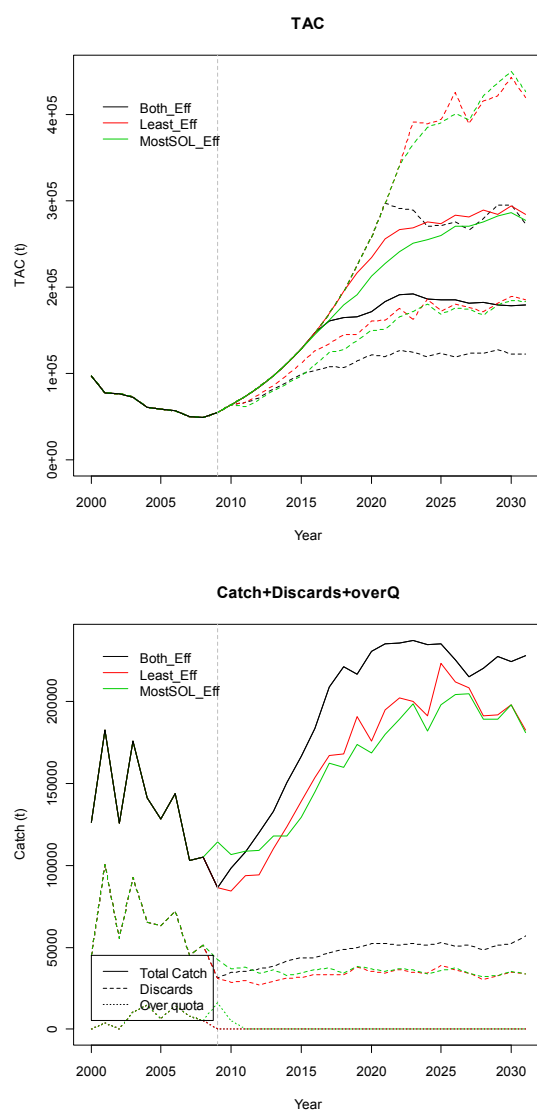


Figure 3.14. Effort by fleet for the plaice and sole stocks under mixed fishery scenario (B6). Time series comprise recorded values prior to 2009, and the median (solid lines) and 90% confidence intervals

(dashed lines) of the projections thereafter. Note: under the *Least_Eff* and *MostSOL_Eff* scenarios the effort by fleet for each stock is the same, for *Both_Eff* plaice (left) and sole (right) differ.

Trends in yield for the plaice and sole stocks are shown in Figures 3.15 and 3.16. For plaice, in all cases the TAC continues to increase initially constrained by the 15% TAC change limit. Overquota is only caught in the case of the *MostSOL_Eff* scenario, and this is only in the first few years when more effort is required to land the sole TAC. The proportion of discards in the catch decreases steadily in all cases, but this proportion is less in the scenarios where effort becomes limiting. For sole, TAC increases initially at a slower rate than that of plaice until levelling off after approximately 10 years. In all cases, except initially under the *Least_Eff* scenario TACs are very similar. Overquota landings in some years are made under all scenarios due to the banking and borrowing which is included in the management for sole (i.e. if the full TAC is not landed in one year, up to 10% can be carried over to the next year).



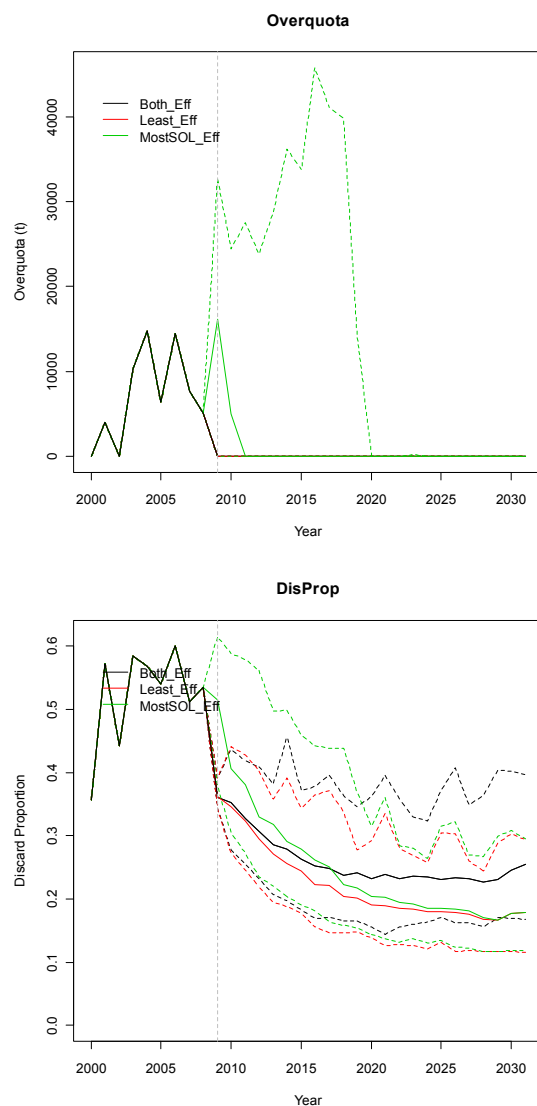


Figure 3.15. Plaice under the mixed fishery scenario (B6): time series of TAC (top left), total catch, discards and overquota (medians only, top right), overquota (bottom left) and discards proportion (bottom right). Time series comprise stock assessment results prior to 2009, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

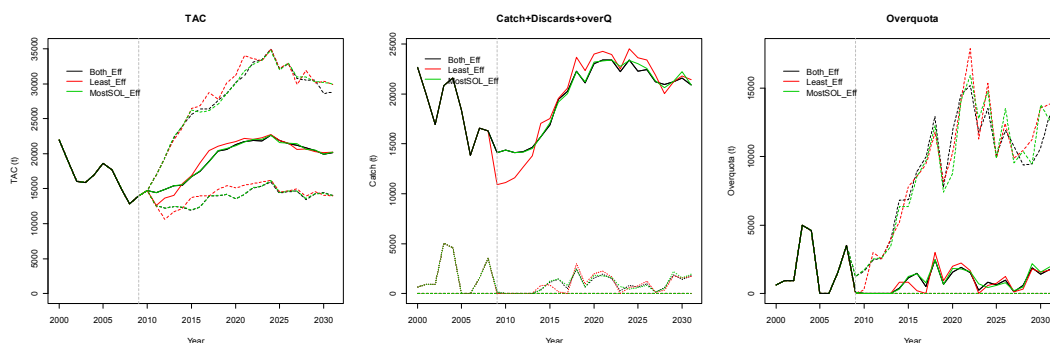


Figure 3.16. Sole under the mixed fishery scenario (B6): time series of TAC (left), total catch, discards and overquota (medians only, middle) and overquota (right). Time series comprise stock assessment results

prior to 2009, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

3.1.6.2. Effects on the stock

The trends in stock growth under the different mixed fishery assumptions are given in Figure 3.17. When effort is restrictive, greater growth in stock size occurs initially, stock size levels off at similar levels in the long term. In the case of the plaice stock, higher catch over most of the period in the *Both_Eff* scenario (in which effort is not limiting) leads to a low long term biomass. However, this is still well above Bpa . In all case for both stocks the risk of failing to be precautionary according to the WKOMSE criterion was less than 5%.

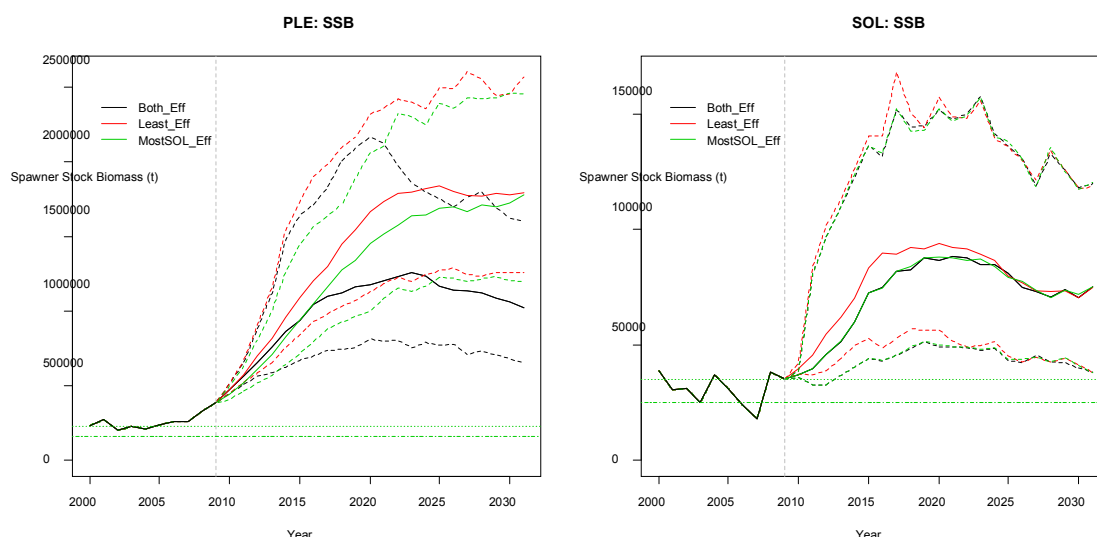


Figure 3.17. SSB under the mixed fishery scenario (B6) for plaice (left) and sole (right). Time series comprise recorded values prior to 2009, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter.

3.2. Tactical options

For both stocks, the greatest effect on long term performance came from choosing different F target values (scenario sets M2 and M3, Table 2.3) in the plan (Tables 3.1 and 3.2). Short term performance was affected more by changes in the allowable TAC variation in the case of plaice, or the size of annual F reduction steps in the case of sole (scenario set M1, Table 2.3).

Increasing the size of F reduction steps has no effect on the plaice fishery because current F is already below the target levels. Increasing the limit in annual TAC change leads to greater catches in the short term (and accompanying SSB reduction), but similar long term values to the current TAC change level. Alternative F targets examined over the range from 0.2 to 0.3 all lead to similar long term TAC values (because these values lie on the flat top of the Fmsy distribution). However, below F=0.2, at for example 0.15, there is a reduction in catch in the medium to long term.

For sole reducing F in 15% steps brings F down to the management target level a few years (2-4) sooner than 10% reductions. This obviously comes at the cost of reduced level of short term TAC in comparison to the 10% reduction option, though, TAC still increases in the short term. Beyond the short term there is no difference, as target F is the determining factor of yields. The TAC change limits for sole are seldom applied and hence

increasing the allowable change has little to no effect on the fishery in the short or long term. However, in the 'worst case' poor recruitment scenario (see section 3.1.5) a greater TAC change limit can mitigate the likelihood of negative impacts. Alternative F target values in the range 0.15 to 0.35 result in both short term and long term differences in TAC. Above 0.3 the long term yield is not significantly higher, but decreasing F below this leads to long term losses in potential catch. An F target of 0.15 produces lower TAC in both the short and long term, while a F target of 0.3 provides higher short term TACs, slowly becoming more similar to the long term TACs from F targets in the 0.2-0.25 range. There is a short term difference between 0.2 and 0.25, though in the long term this is less substantial (0.25 slightly higher).

Table 3.1. Plaice yields and likelihoods of meeting WKOMSE precautionary criteria (risk to stock) under different targets Fs in the multi-annual plan.

F	Yield		Risk to stock		
	ST (2011-2015)	MT (2016-2025)	ST (2011-2020)	MT (2016-2025)	LT (2021-2030)
0.15	69357	97825	NA	NA	NA
0.2	73307	112434	NA	NA	NA
0.22	*	*	*	*	*
0.23	79190	124038	0	0	0
0.25	82168	124938	0	0	0
0.3	93044	130710	0	0	0
0.35	*	*	*	*	*

* = Not run for this stock.

Table 3.2. Sole yields and likelihoods of meeting WKOMSE precautionary criteria (risk to stock) under different targets Fs in the multi-annual plan.

F	Yield		Risk to stock		
	ST (2011-2015)	MT (2016-2025)	ST (2011-2020)	MT (2016-2025)	LT (2021-2030)
0.15	14365	15904	NA	NA	NA
0.2	14512	17687	0.1	0.05	0.02
0.22	14531	18215	0.1	0.05	0.02
0.23	*	*	*	*	*
0.25	14615	19151	0.1	0.06	0.06
0.3	14645	20236	0.14	0.14	0.19
0.35	15886	20568	NA	NA	NA

* = Not run for this stock.

The general pattern of stock development of plaice under the various management scenarios evaluated was an increasing trend in SSB in the short term (roughly 5 years) followed by a leveling off of median SSB. Alternative F targets in the 0.15 to 0.3 range lead to the stock stabilising at different levels of SSB, all above Bpa and precautionary with regards to the limit reference points in the short and long term. Given the healthy condition of the plaice stock and the current low levels of F being exerted on the stock, these low risk levels are not surprising.

The sole stock also shows a general pattern of increase under the scenarios examined, although this increase is slower initially and it takes longer for the stock to stabilise at a higher level (roughly 10 years). Although the sole stock is currently believe to be slightly above Bpa, F remains high and this has implications on stock growth in the short term. Because there is a risk of poor incoming recruitment leading to the stock dropping below Blim, the multi-annual plan was not found to be precautionary in the short term (i.e. first 10 years), for most of the management option evaluated. Increasing the reduction of F to 15% steps brings F down to the management target level quicker and allows for a increase in stock size. This increases the likelihood of the management plan being precautionary in the medium term (<5% risk according to WKOMSE criterion), although long term differences are negligible. An F target of 0.25 does not lead to stock levels that can be considered precautionary for any of the three ten year time periods examined (6% chance of not being precautionary in the last ten years, 2021-2030). The risk at an F target of 0.15 or 0.2 is similar, with both being precautionary for 2016-2025 and longer term, but not in the short term. This indicates that the estimated Fmsy (ignoring risk) for this stock (in the region of 0.36) poses to high a level of risk to the stock, as any F targets above 0.3 were not found to be precautionary over any time period. It is considered that it is important to take the risk into account when setting the target F for sole.

Detailed results for the various management scenarios are shown in sections 3.2.1-3.2.3.

3.2.1. M1 – HCR options

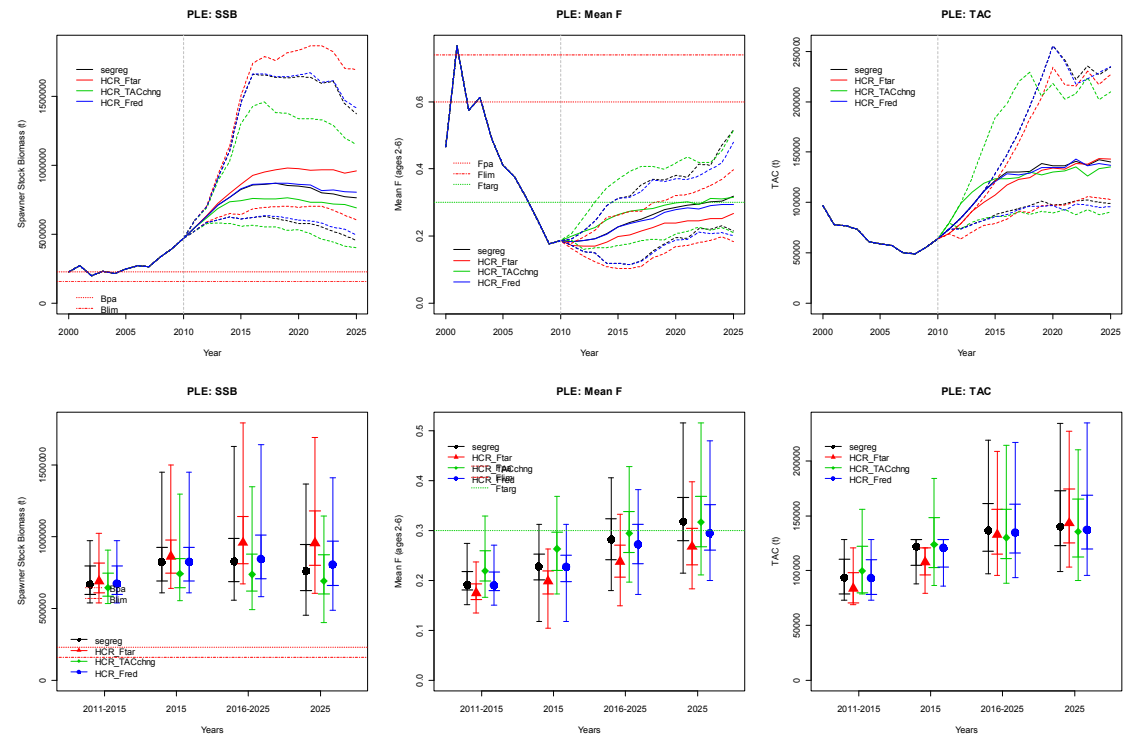


Figure 3.18. Plance under the HCR options scenarios (M1): SSB (left), mean F (middle) and TAC (right). Time series comprise stock assessment results prior to 2009, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter (top); and range plots of point values and averages over the short- and medium-term (bottom).

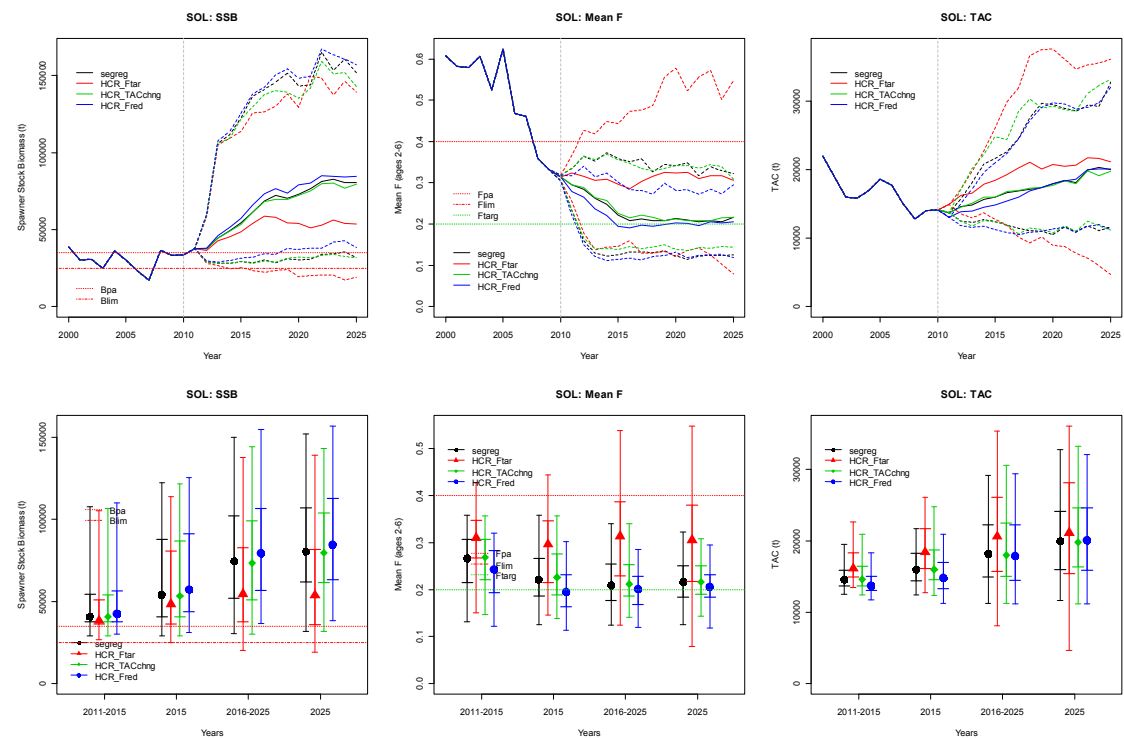


Figure 3.19. Sole under the HCR options scenarios (M1): SSB (left), mean F (middle) and TAC (right). Time series comprise stock assessment results prior to 2009, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter (top); and range plots of point values and averages over the short- and medium-term (bottom).

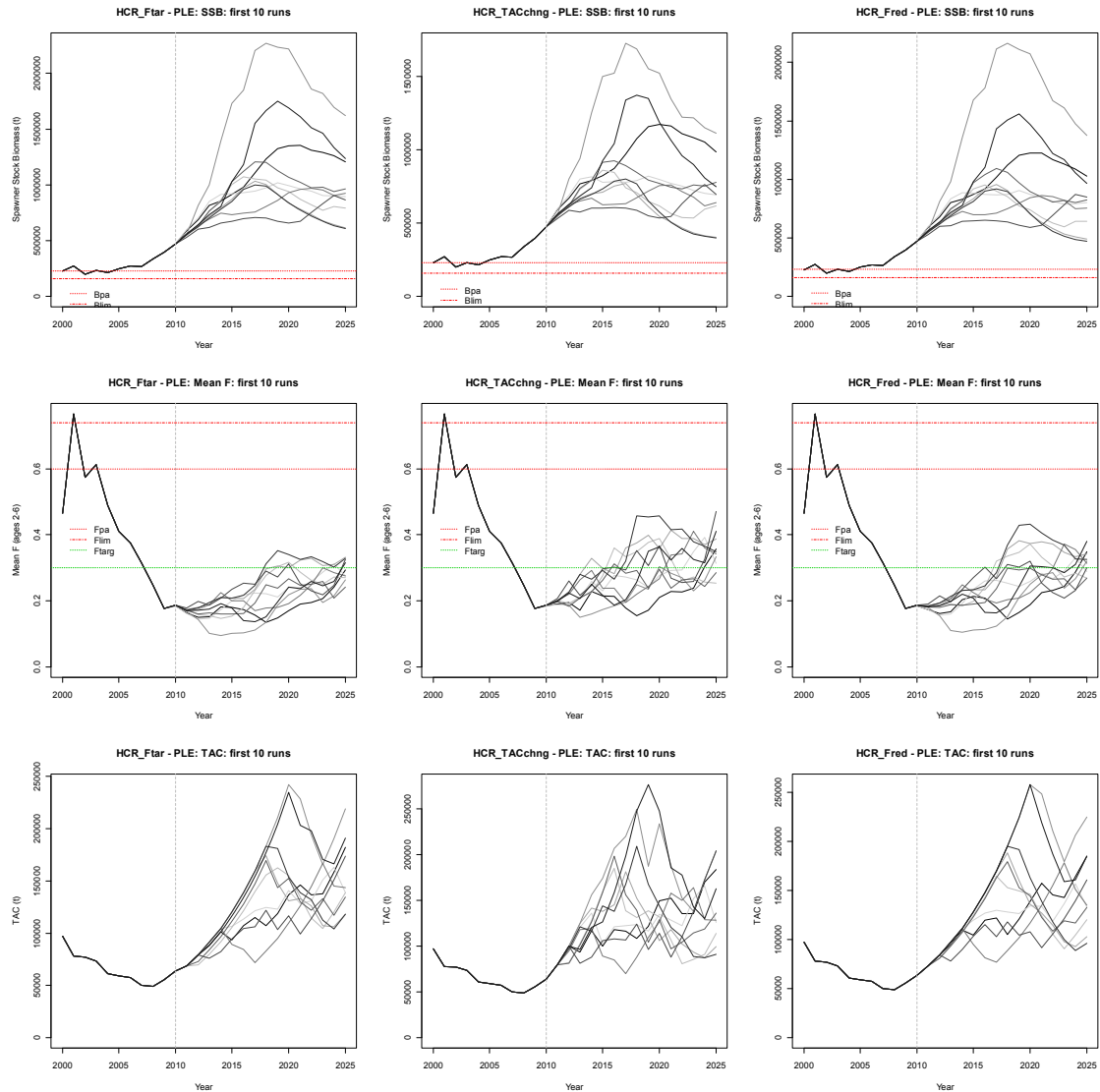


Figure 3.20. Plaice under the HCR options scenarios (M1): ‘worm plots’ showing individual trajectories of the first ten replicates of SSB (top) and mean F (middle) and TAC (bottom) for each of the scenarios. Time series comprise stock assessment results prior to 2009 and projections thereafter.

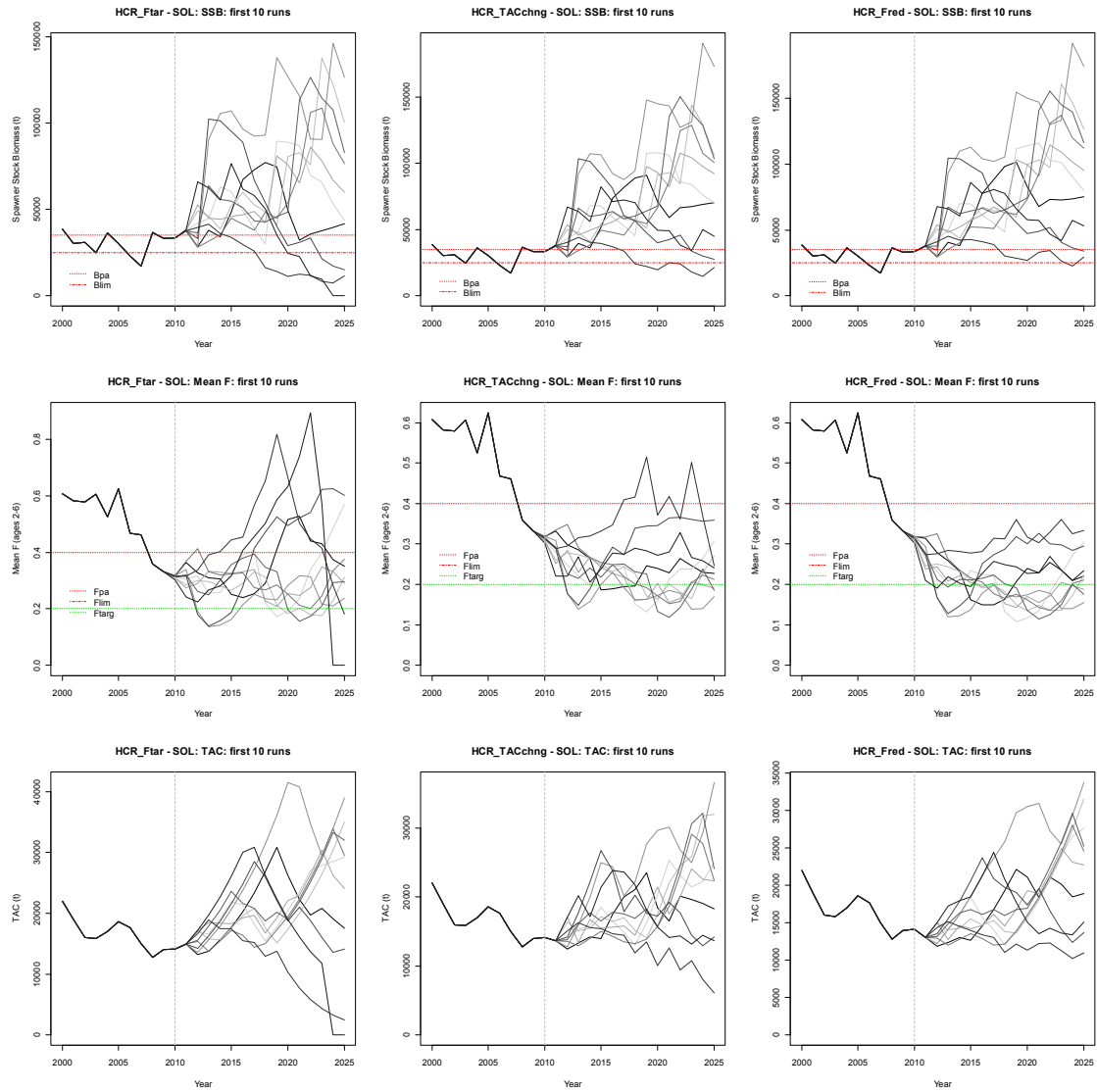


Figure 3.21. Sole under the HCR options scenarios (M1): ‘worm plots’ showing individual trajectories of the first ten replicates of SSB (top) and mean F (middle) and TAC (bottom) for each of the scenarios. Time series comprise stock assessment results prior to 2009 and projections thereafter.

3.2.1.1. Effects on the fishery

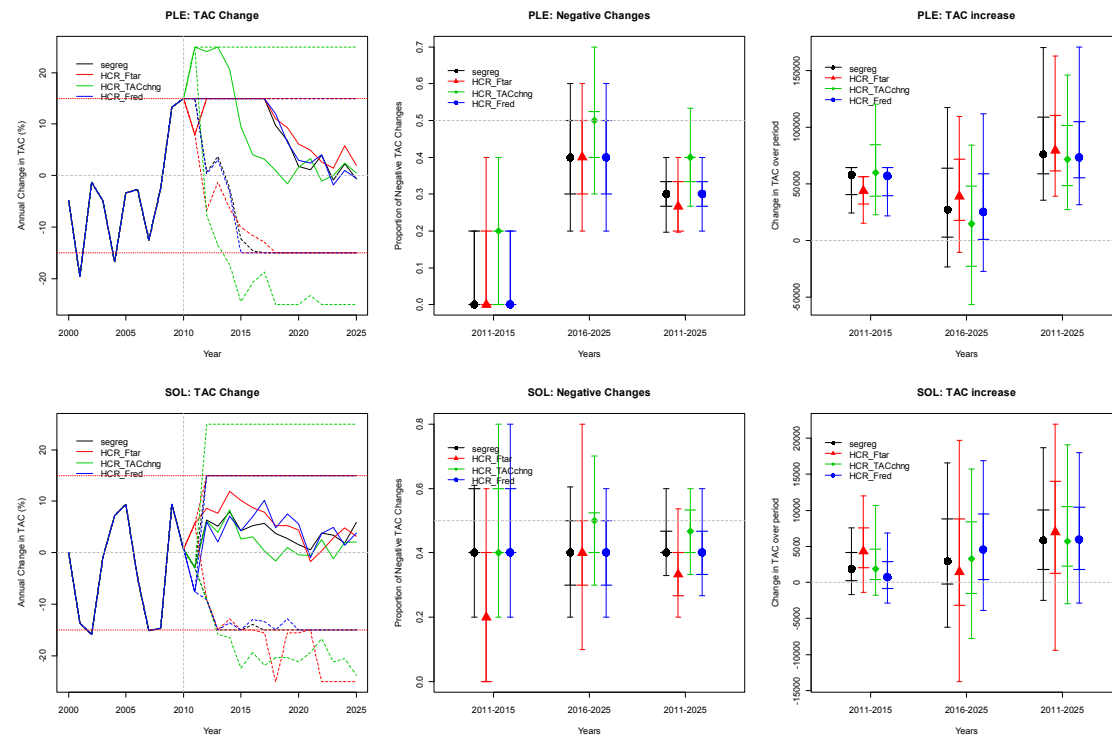
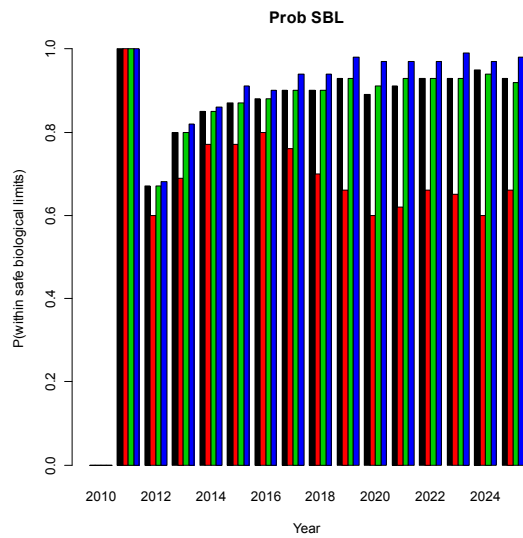


Figure 3.22. TAC variability under the HCR options scenarios (M1) for plaice (top) and sole (bottom): annual variation in TAC observed values prior to 2009, and the median (solid lines) and 90% confidence intervals (dashed lines) of projections thereafter; proportion of negative changes in TAC and actual change in TAC of various time periods.

3.2.1.2. Effects on the stock



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3.2.2. M2 – Exploratory alternative F target range

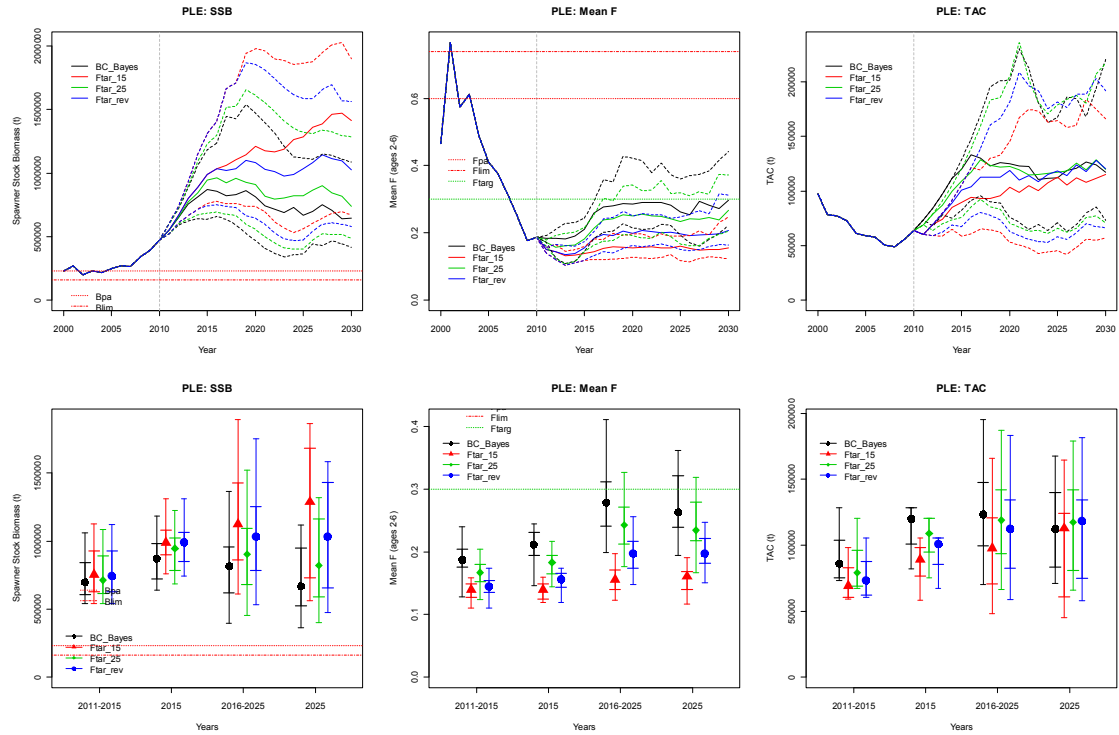


Figure 3.24. Plance under the exploratory F target range scenarios (M3): SSB (left), mean F (middle) and TAC (right). Time series comprise stock assessment results prior to 2009, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter (top); and range plots of point values and averages over the short- and medium-term (bottom).

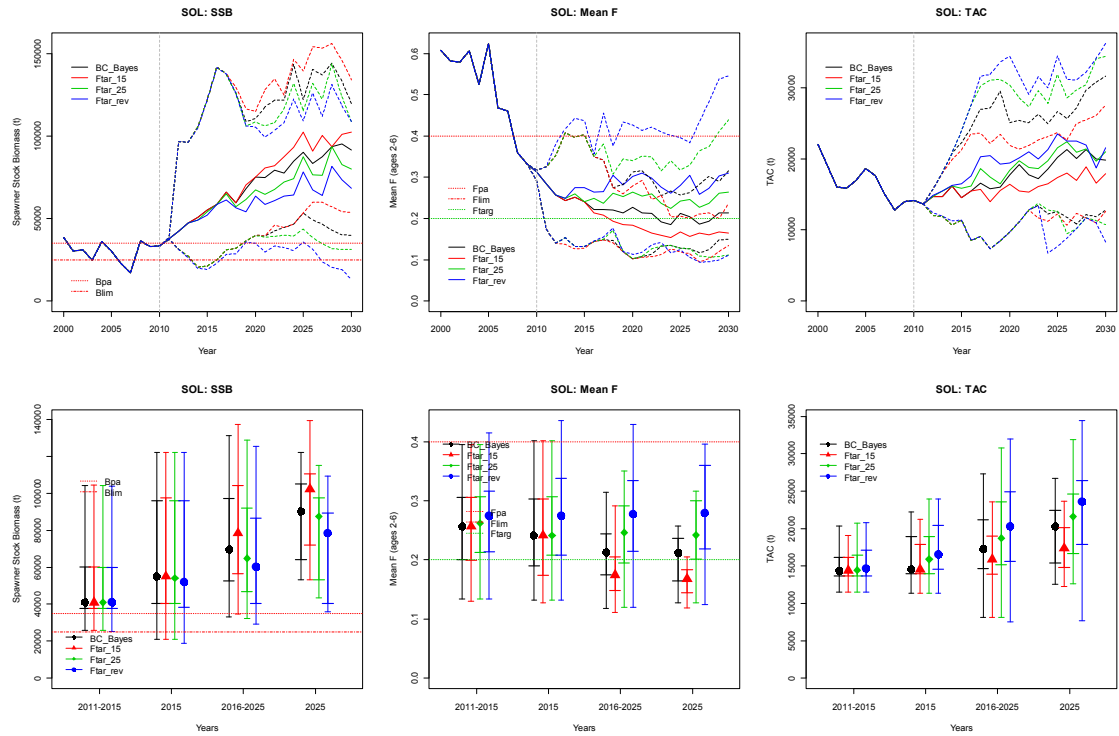


Figure 3.25. Sole under the exploratory F target range scenarios (M3): SSB (left), mean F (middle) and TAC (right). Time series comprise stock assessment results prior to 2009, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter (top); and range plots of point values and averages over the short- and medium-term (bottom).

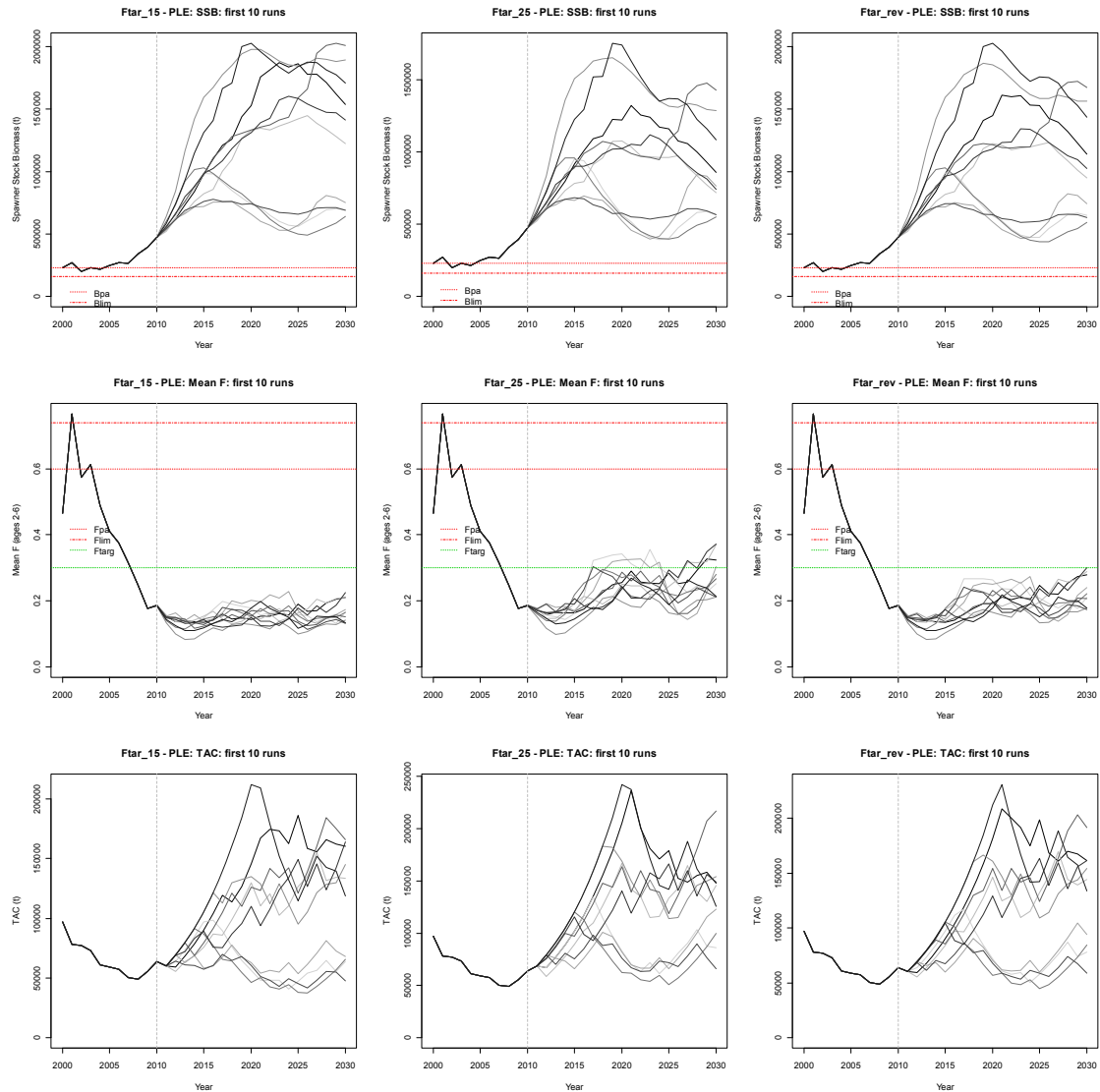


Figure 3.26. Plaice under the exploratory F target range scenarios (M3): ‘worm plots’ showing individual trajectories of the first ten replicates of SSB (top) and mean F (middle) and TAC (bottom) for each of the scenarios. Time series comprise stock assessment results prior to 2009 and projections thereafter.

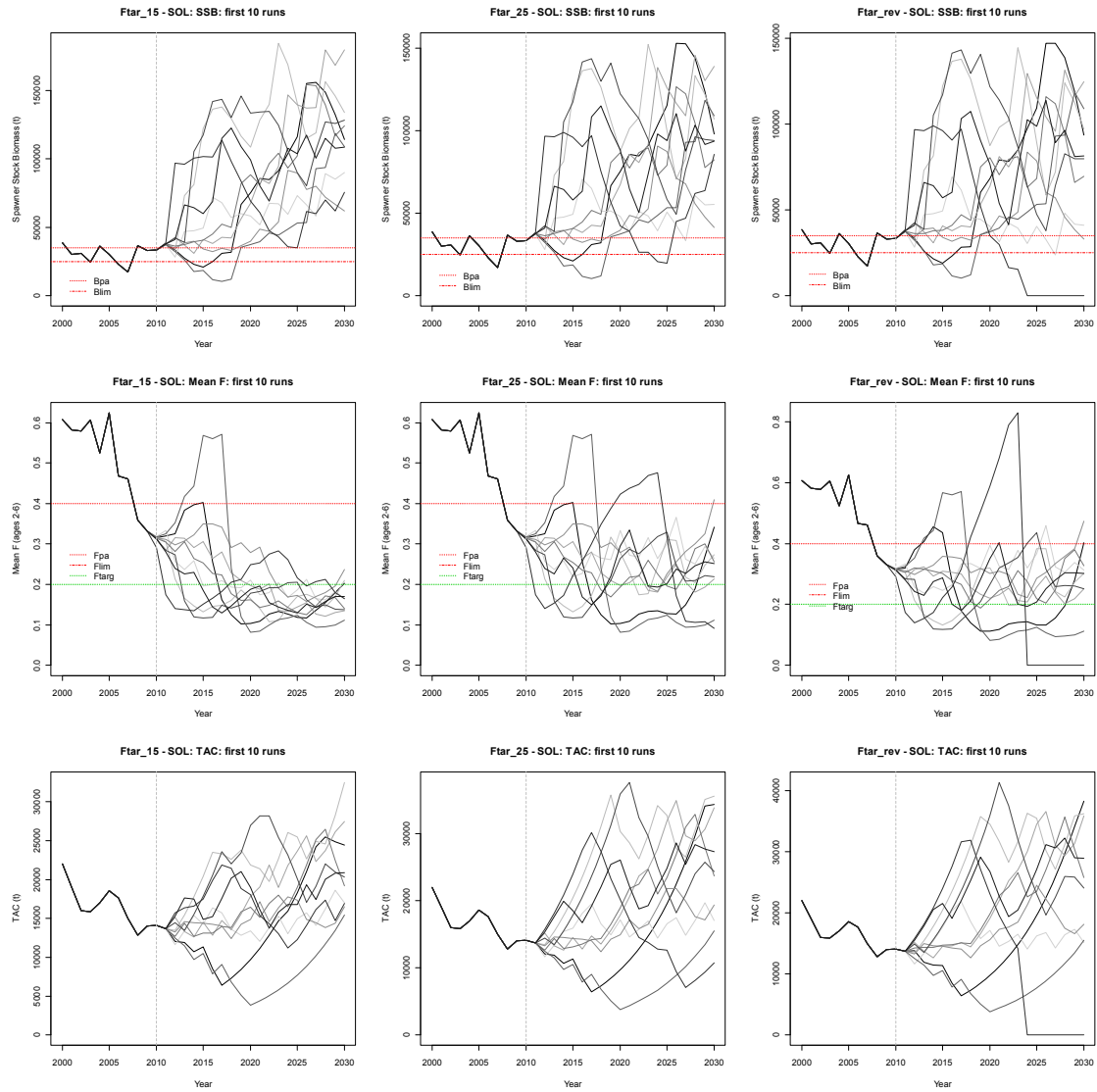


Figure 3.27. Sole under the exploratory F target range scenarios (M3): ‘worm plots’ showing individual trajectories of the first ten replicates of SSB (top) and mean F (middle) and TAC (bottom) for each of the scenarios. Time series comprise stock assessment results prior to 2009 and projections thereafter.

3.2.2.1. Effects on the fishery

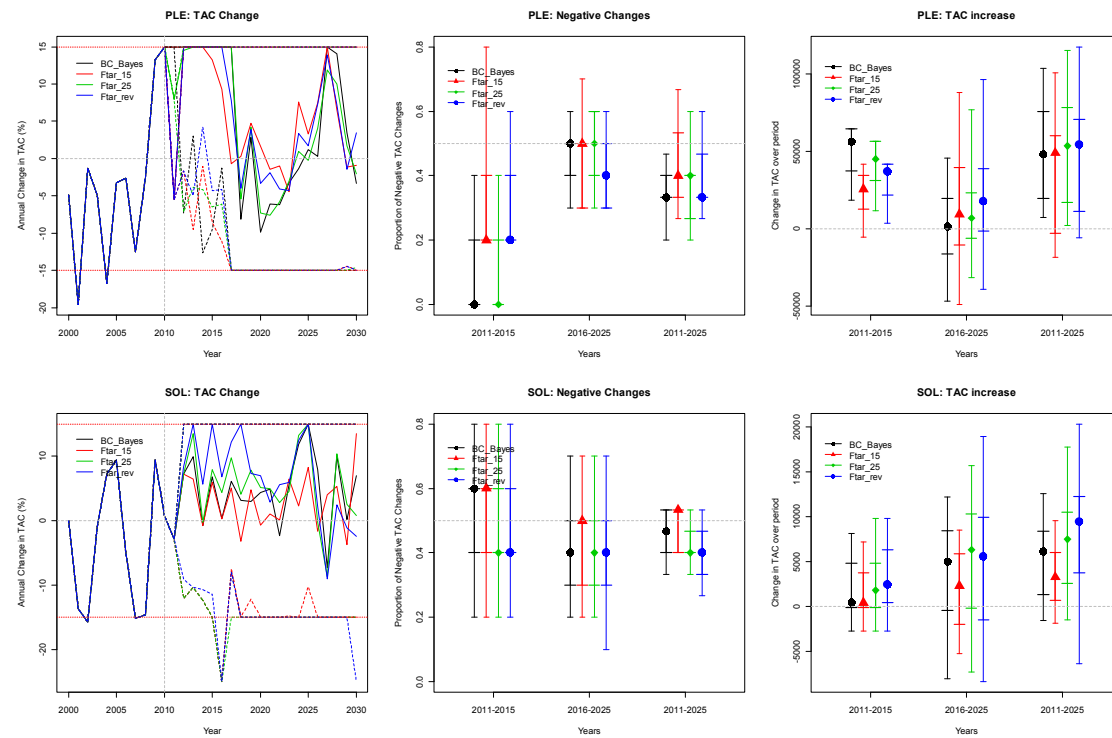


Figure 3.28. TAC variability under the exploratory F target range scenarios (M3) for plaice (top) and sole (bottom): annual variation in TAC observed values prior to 2009, and the median (solid lines) and 90% confidence intervals (dashed lines) of projections thereafter; proportion of negative changes in TAC and actual change in TAC of various time periods.

3.2.2.2. Effects on the stock

Due to the limited number of replicates in these scenarios, the probabilities of being precautionary are poorly estimated and therefore not shown here.

3.2.3. M3 – Alternative F targets

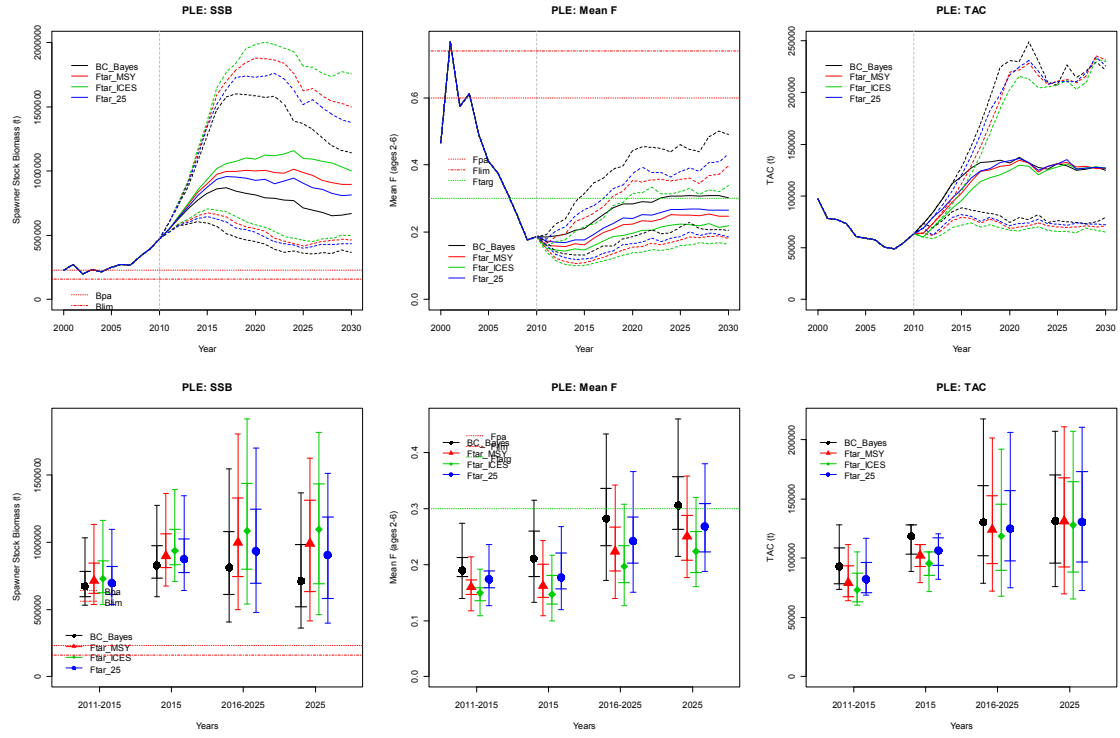


Figure 3.29. Plance under the alternative F targets scenarios (M3): SSB (left), mean F (middle) and TAC (right). Time series comprise stock assessment results prior to 2009, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter (top); and range plots of point values and averages over the short- and medium-term (bottom).

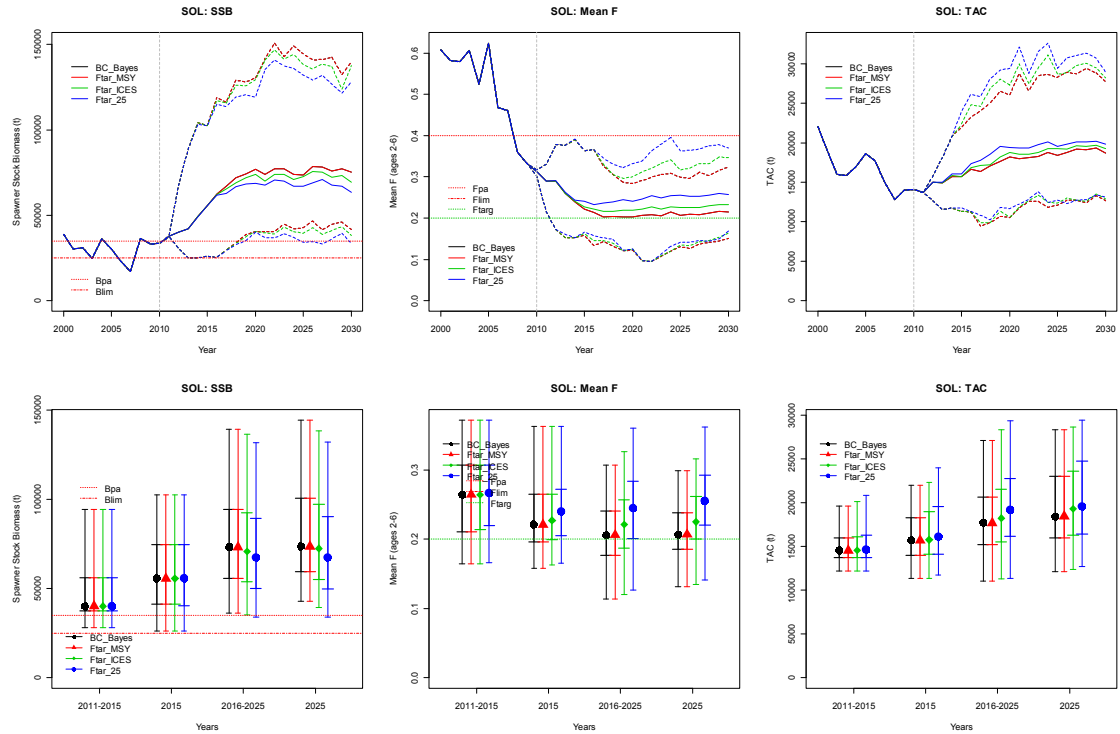


Figure 3.30. Sole under the alternative F targets scenarios (M3): SSB (left), mean F (middle) and TAC (right). Time series comprise stock assessment results prior to 2009, and the median (solid lines) and 90% confidence intervals (dashed lines) of the projections thereafter (top); and range plots of point values and averages over the short- and medium-term (bottom).

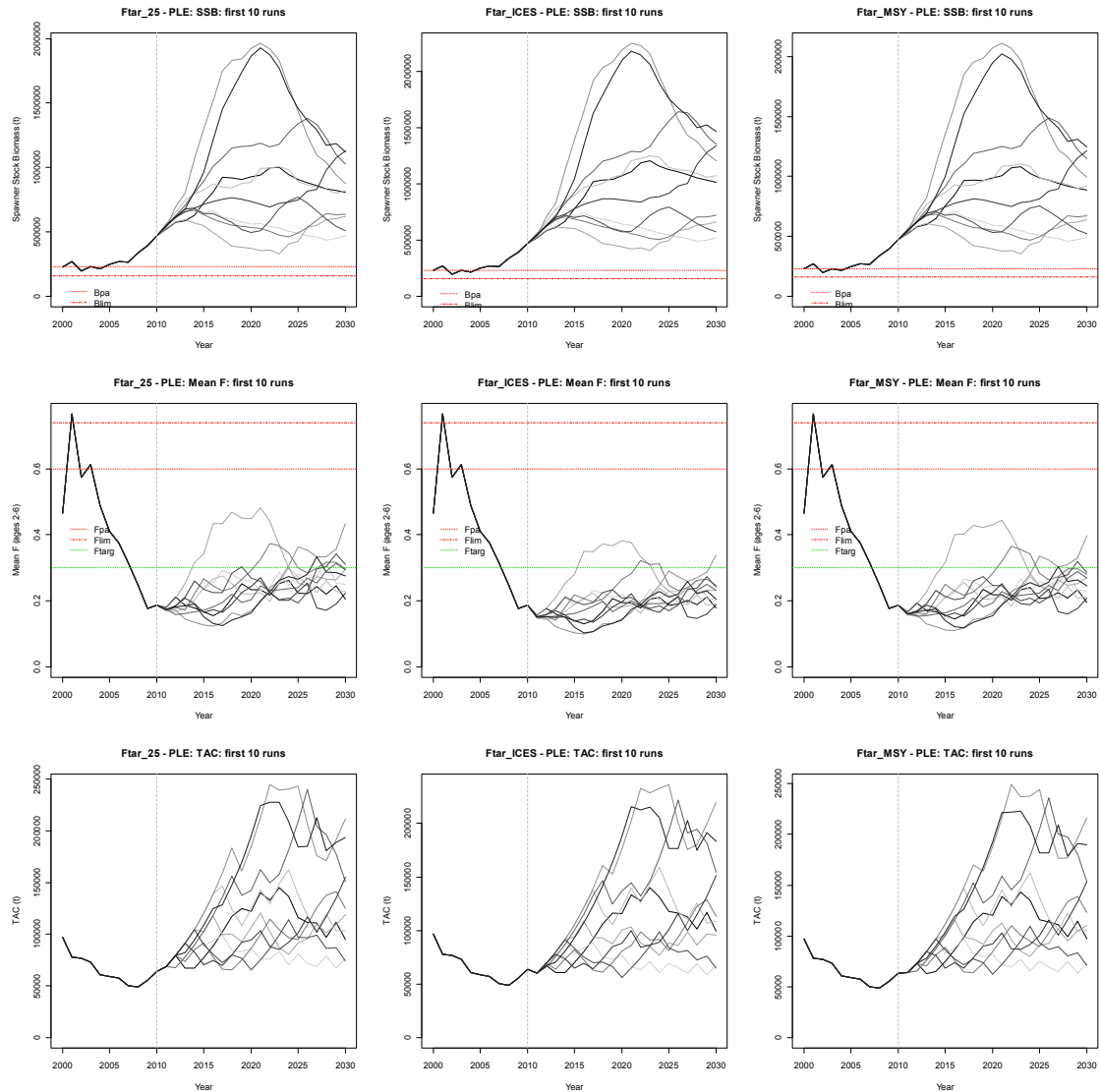


Figure 3.31. Plaice under the alternative F targets scenarios (M3): ‘worm plots’ showing individual trajectories of the first ten replicates of SSB (top) and mean F (middle) and TAC (bottom) for each of the scenarios. Time series comprise stock assessment results prior to 2009 and projections thereafter.

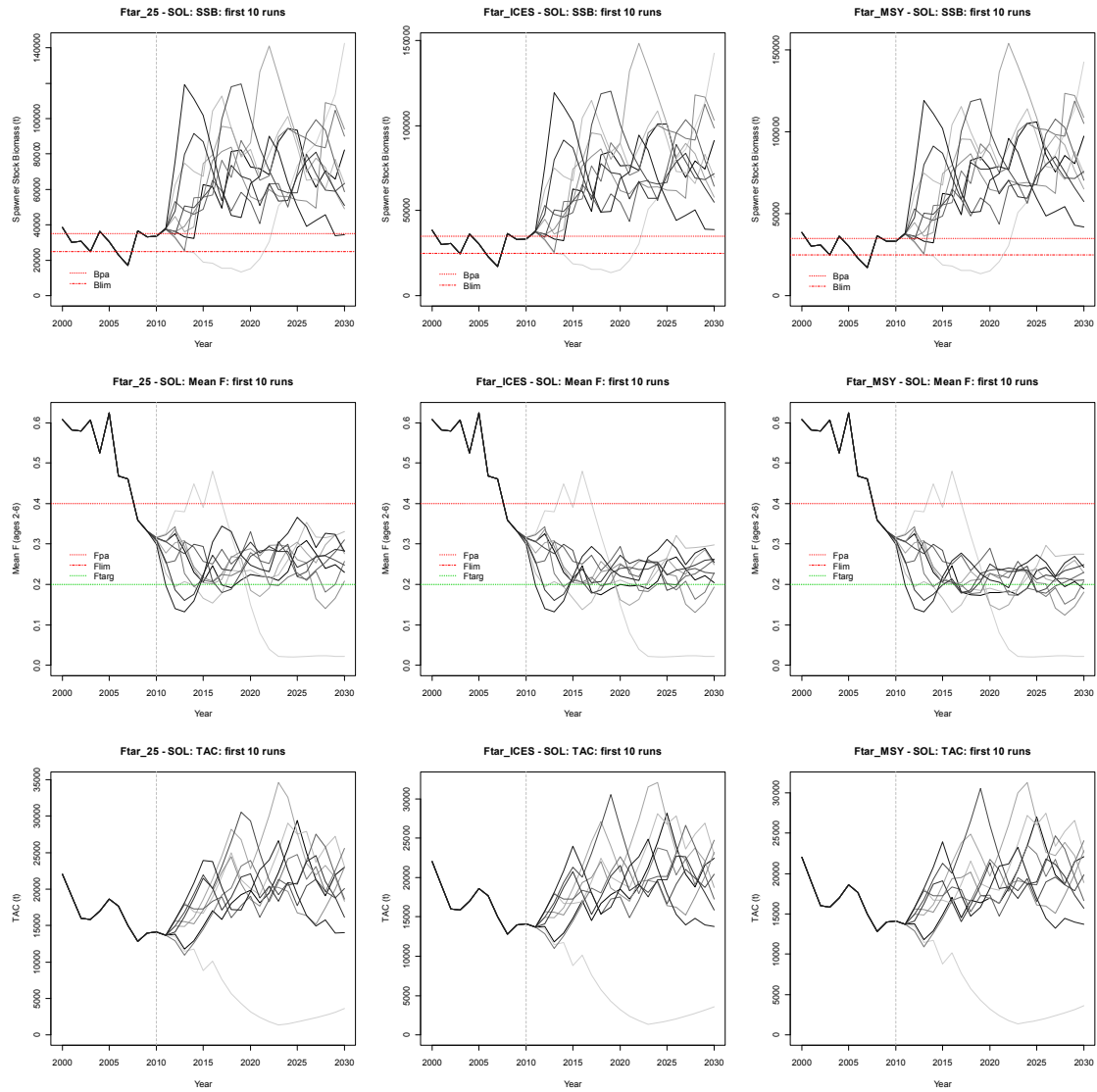


Figure 3.32. Sole under the alternative F targets scenarios (M3): ‘worm plots’ showing individual trajectories of the first ten replicates of SSB (top) and mean F (middle) and TAC (bottom) for each of the scenarios. Time series comprise stock assessment results prior to 2009 and projections thereafter.

3.2.3.1. Effects on the fishery

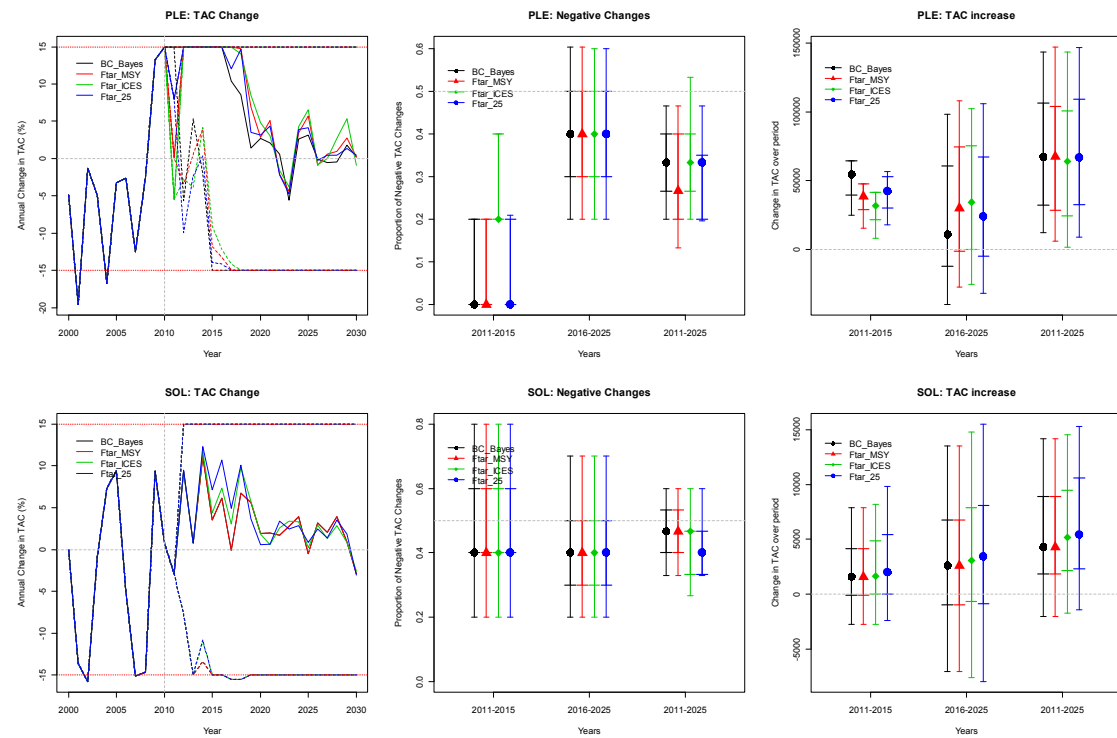


Figure 3.33. TAC variability under the alternative F targets scenarios (M3) for plaice (top) and sole (bottom): annual variation in TAC observed values prior to 2009, and the median (solid lines) and 90% confidence intervals (dashed lines) of projections thereafter; proportion of negative changes in TAC and actual change in TAC of various time periods.

3.2.3.2. Effects on the stock

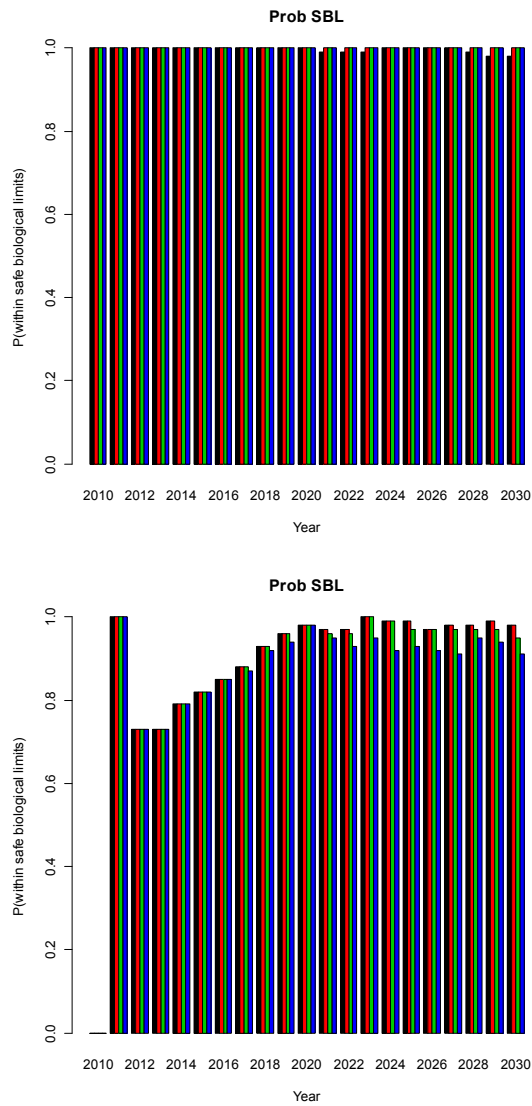


Figure 3.34. Probability of being within safe biological limits under the HCR options scenarios (M1) for plaice (left) and sole (right). Legend as per previous figure.

4. DISCUSSION

The results presented in this annex show the biological and fishery consequences from a number of plausible scenarios. The results could be looked at in terms of economic consequences, but no economic feedback into management loop within the simulations is incorporated. Under the range of biological scenarios examined, the long term trends in stock development and TAC did not show any notable differences that would invalidate the use of the base case scenario. Therefore these results suggest that the base case scenario is adequate to evaluate the performance of alternative management options.

The evaluation suggests that the multiannual plan can be considered to be precautionary for both of the managed stocks according to the criteria described by WKOMSE (ICES 2009a) for the evaluation of multiannual plans. The plan allows for increases in yield in the long term while reducing the current levels of F . There is a very high likelihood of stock growth in terms of SSB for both stocks.

The current F target for the plaice stock does not produce significantly higher long term yields relative to F_s in the range 0.2-0.3. It does however result in a lower long term biomass median and therefore a potential higher risk to the stock (though all scenarios examined showed very low risk to the stock). An F target in the range 0.2-0.25 is acceptable (similar yields, but safer), could potentially be set to 0.23 (the estimated F_{msy} for this stock using the Bayesian method, Annex C). A lower target F , in addition to reducing discard proportion and potentially reducing the ecosystem impact of the fishery, would also increase coherence with sole target. Figure 11.1 shows the mean F of the plaice stock in relation to that of the sole stock. Since the mid 1960s this ratio has been below that implied by the targets in the multi-annual plan. Assuming the sole target remains unchanged, using the long term average ratio (long term mean $F_{ple}:F_{sol} = 1.18$), would result in a target of 0.23 or 0.24 for the plaice stock, which is nearer the estimated F_{msy} level and also near to current levels of F exerted on the stock.

The target F for sole could be increased slightly, but this should not exceed $F=0.25$. An increase in F target might lead to higher catches, but the risks associated with increase in target F are considered to be not precautionary ($F = 0.25$ is not precautionary). Increasing the size of F reduction steps, to get nearer target F more quickly might be beneficial in the medium term, as the current plan is not precautionary in short term, but risks reduce in medium term. Such an approach would allow the stock to recover more quickly to give a healthy springboard to launch sustainable, high yield management. In the ‘worst case’ poor recruitment scenario (see section 3.1.5) a greater TAC change limit can mitigate the likelihood of negative impacts. Though it may not be necessary to change the limits in the plan, but rather obtain a better criteria under which increases changes to management can be applied if the stock is perceived to be declining too quickly or at too low an SSB. Potentially there is a need for a different clause (besides safe biological limits as currently stated in Article 18 of the multi-annual plan) for ‘exceptional circumstances’ (i.e. when to increase reactivity), for example, an alternative biomass point slightly higher than B_{pa} (which is very near to B_{lim}) or if mean recruitment level over a recent time period is below a certain level.

GES objectives hard to define, so have been difficult to build into plan. Some potential GES targets are presented (mean age and age diversity, and discards proportion in the case of plaice), however interpretation of these is difficult in the absence of any defined reference points for a healthy stock according to these criteria. Having a lower proportion of discards in the catch of plaice could be seen as a more ecosystem—friendly result of the management plan. Results show, as expected, that a decrease in F level (and the associated effort required to land the TAC) leads to a lower proportion of discards in the catch. Over the range of F targets evaluated, all showed a short term decrease in discards proportion, levelling off at a lower level in the region of 20-30% discards. Likewise, a reduction in effort, limiting it below 2006 levels as specified in the plan, is likely to reduce the overall ecosystem impact of the dominant beam trawl fishery. It should also be noted that in the last 2 years some of the Belgian and Dutch beam trawl vessels have switched to use a “twin rig” gear, which may be considered as a first step in the right direction of a more ecosystem friendly fishery.

Caution needs to be taken in the interpretation of the MSE, and stock projection, results because future projections take the stock to outside the range of historic observations. It is likely that in reality such changes in stock status would not proceed unchecked. Density-dependent growth or mortality would impact on the stock at such sizes and fishing patterns and selectivity would likely change. This evaluation does not aim to predict exactly what would happen if the multiannual plan continues to be implemented in the long term. The evaluation aims to assess whether the plan is robust to future process error and various assumptions of stock dynamics. It further aims to assess the degree of certainty with which we can accept that it is likely to be both precautionary and allow for the high long term yields while maintaining healthy stocks. The models should be used as indications more than absolute projections into the future. By examining the performance of the plan at the lower ends of the simulation ranges and considering 'worst case' recruitment scenarios the likely risk of a management failure can be assessed. This is embodied in the WKOMSE criteria used to evaluate the results.

A number of simplifying assumptions were required for the implementation of the MSE. For both plaice and sole stocks it has been assumed that productivity of the marine ecosystem in the projected period will remain within the same range as has been observed in the past 50 years. Though this assumption is likely to be flawed, it is the most reasonable assumption to make given the availability of data and the fact that incorporating potential future regime shifts would be largely speculative. Observations of changes in the species composition in the North Sea towards more southern species and observation on changes in stock dynamics of some other stocks may indicate that external factors, such as climate change, do also affect the ecosystem. In the evaluation, it has also been assumed that annual decisions will be made using certain assessment methods (the present assessment procedures) with their associated uncertainties. It can be envisaged that other methods may be used in the future and this may affect (improve or deteriorate) the effect of the measures. In the current model spatial variation in fish abundance and fishing effort is not included. Conditioning of a model with spatial differentiation is complicated (Pastoors et al. 2006; Poos et al. 2006) and the (XSA) observation model to which the results are compared don't include spatial variation either. When evaluating the model, assumptions had to be made at different levels in the process. If these assumptions are very different from the true situation, the effect of the measures may be different than indicated by the evaluation. Two major assumptions that were identified for this analysis were the initial starting condition of the two stocks and the form of the stock recruit relationship. By assessing ranges of these two factors in different scenarios it was possible to determine the plan is sensitive to assumptions about them. The present results suggest that the multiannual plan is effective across a broad range of stock conditions, for both plaice and sole, maintaining a healthy stock while keeping F levels low in all cases. It also performed effectively at even the lowest likely future recruitment. These results show the multiannual plan to be robust to uncertainty in initial starting condition and future recruitment.

In most simulations the link between plaice and sole fishery in the initial evaluations was limited. This led to an evaluation of how different assumptions on mixed fisheries behaviour are likely to impact on the stock. The effort required to land the sole TAC is initially higher than that for the plaice TAC due to high levels of F in the sole fishery compared to low levels in the plaice fishery. As plaice TACs increase more rapidly than those of sole, accompanying opposite trends in F (decrease in sole and increase in plaice), this leads to the TAC of plaice requiring more effort to land in the long run. This is a more tractable and favourable situation for the mixed fishery to be in because overquota of sole can be more easily avoided than that of plaice. None of the assumptions of mixed fisheries behaviour invalidated any of the previous conclusions, in fact suggesting that for plaice the management plan is likely to be more precautionary. These findings also suggest that because of technical measures that could increase plaice catch while limiting sole impact, the coupling of both for the start of stage 2 of the plan is restrictive. Plaice has been within safe biological limits for more than two consecutive years, but exploitation is held back by the state of the sole stock. If this situation was reversed it would be necessary to hold back the start of stage two, but in the current situation, reining in the plaice fishery has limited benefit to the state of the sole stock.

5. CONCLUSIONS

There are indications that a target of $F = 0.23$ for plaice would be a more appropriate F target for MSY. This might also be more in line with F target for sole. Currently the target F s are not well aligned and the change in

target F for plaice suggested above, without a change in sole target, may help this. The long term matching of these targets will always be a potential problem. While the plan for plaice appears robust to stock collapse through recruitment failure, the same is not the case for sole unless some additional action is taken. Such action is implied in the management plan but is not explicitly described. It is considered that the best trigger for remedial action should be a value for mean recent recruitment, though the most suitable period and value has not yet been determined. The mixed fisheries scenarios suggest that because of technical measures that could increase plaice catch while limiting sole impact, the coupling of both for the start of stage 2 of the plan is restrictive.

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ANNEX C: DYNAMIC EQUILIBRIUM DIAGNOSTICS FOR NS PLAICE AND SOLE

WD for SGMOS 10-06 Vigo 18-22 October 2010 by EJ Simmonds, European Commission, JRC, Ispra Italy

1. The objective

To provide summary of historic exploitation, and stochastic equilibrium exploitation with estimates of probability of $F=F_{msy}$.

This is not a Management Strategy Evaluation (MSE). The methodology does not include implementation or measurement errors or and restrictions on catch variability to provide economic stability. It provides a general diagnostic of exploitation under fixed target F s and does not include out of equilibrium conditions that would exist under MSE. Thus it gives a guide for targets and range of outcomes in an error free world.

2. Methods

Data is taken from ICERS 2009 assessments of NS plaice and sole (ICES 2009) using SSB/R pairs from 1957-2007. The uncertainty in modeling is chosen to match the assessment

Populations are parameterized as 1000 separate populations that includes:-

- Selection at age in the fishery drawn at random 2004-2008

- (selection of age for plaice includes estimated partial, F for discards)

- Weights at age in the catch drawn at random 2004-2004

- Weights at age in the stock drawn at random 2004-2004

and as they are not varying the assessment does not include:-

- Annual variability in maturity

- Annual variability in time of spawning

Annual variability in timing of fishery

Annual variability in natural mortality

6.1.1. Recruitment

Recruitment is modeled through stochastic multiple model based simulation for the populations. Individual populations follow a single stock/recruit model to define functional dependence of recruitment on SSB and a stochastic component to mimic unpredictable environmental influences. The set of models are based on Bayesian analysis to give a joint distribution of model coefficients (A,B and σ) for each functional type. The proportion of functional types is chosen using the method of Kass and Raftery (1995). The procedure is documented in Simmonds et al (2011) for the example of NE Atlantic mackerel. Here the S-R functions chosen are Hockey-Stick and Ricker.

Hockey-stick model	$\exp(\log(A*B)+\text{RND}(\sigma))$	(SSB>B)
	$\exp(\log(A*SSB)+\text{RND}(\sigma))$	(SSB<B)
Ricker model	$\exp(\log(A*SSB*\exp(-B*SSB)) + \text{RND}(\sigma))$	

Simulation of exploitation is carried out at a range of constant F exploitation with selection at age as described above. The populations are taken to equilibrium by exploitation for 100 years and run a further 50 years to obtain equilibrium values for distribution of recruitment, SSB, catch and landings.

6.1.2. Model probability

Rather than pick a single model or a model type with a range of coefficients, multiple functional forms are included. The proportions of each model type j is selected based on the harmonic mean ($L_j = 1/\text{mean}(1/\Pi_j)$) of the likelihoods Π_j of the estimated model set. Then the proportions for model L_1 is estimated as $L_1/(L_1+L_2+....)$ and similarly for model 2.

As the probability depends on the number model sets included its important to use a balanced set of models each set implying a different biological relationship. In this case there are two potential biological hypotheses either that S-R declines or is independent of SSB at high biomass. The two model types chosen are Ricker and Hockey-Stick. In this case Hockey-Stick is preferred over Beverton and Holt as the former can include specific limits to the slope

at the origin based on the data, whereas parameterising the slope at the origin for the later is difficult.

3. Results

6.1.3. Recruitment models

The parameter distributions and fitted models are shown in Figures C1 and C2 for North Sea plaice and sole respectively. Based on DIC criteria for both NS sole and NS plaice model selection based on best fit criteria (Table C1) prefers Hockey-Stick over Ricker. Such criteria selects the most probable model. Here we do not choose between models but use an additional method to obtain model probability. This approach considers the full distribution of parameters the resulting probabilities of the different model types are different for the different stocks, because the fits have different precision. For NS sole Ricker / Hockey-Stick is split 61 / 39% respectively and for NS plaice the choice is reversed Ricker / Hockey-Stick is split 42 / 58% respectively (Table C1).

Table C1 Bayesian model fit criteria (DIC) and model set probability for Hockey Stick and Ricker models for NS plaice and sole

	Model pD	Effective No of Parameters	DIC	Model Probability
NS sole	Hockey Stick	1.917	120.432	0.391
	Ricker	2.871	120.886	0.608
NS plaice	Hockey Stick	2.133	79.543	0.583
	Ricker	2.255	79.899	0.417

6.2. Simulated recruitment

To simulate the recruitment the mean R is obtained based on SSB and the functional relationships given above. A random component based on a normal distribution in the log domain gives log normal distribution around the geometric mean (though the mean depends on SSB). A comparison of observed and simulated values is given in Figure C3. It can be seen from the cumulative distributions (which are not truncated) that the choice of distribution fits well at the high end and poorly at the low end for plaice; for sole the fit is more symmetrical. As the fitted distribution is used to draw many thousands of values and is an unlimited and

continuous it is possible to drawn unrealistically large or low recruits that have not been observed in nature. To give values that correspond more closely to the observed range values at the extremes of the distributions simulated values are truncated a small amount above and below the observed values. Truncation limit are obtained from the observations by limiting the distribution by $\frac{1}{2}$ increment above and below highest and lowest observed recruitment. The truncation values are implemented as limits to the distribution , and thus depend on SSB. They are shown as red dots on the cumulative distributions. The resulting simulated populations for a range of SSB are also shown in Figure C3.

The multiple model approach does not better describe the true populations rather it attempts to include the uncertainty in what we know about the form of the S-R relationship in the evaluations. It ensure that we take account of that uncertainty in evaluating the risks.

6.2.1. *Simulated populations*

The results of the equilibrium exploitation are shown in Figures C4 and C5 for NS plaice and sole respectively. For NS sole catches and landings are assumed to be equal. For NS plaice discards are explicitly included and landings and catches are shown separately.

These plots show the equilibrium conditions, for comparison the historic values of Recruitment SSB and catch are shown against F. It is important to remember that these can be under non-equilibrium conditions. So historic observations to the right of the lines imply outcomes with declining stocks and points below or to the left, of which there are very few, imply expanding stocks.

The optimal exploitation F for these stocks, under conditions of zero measurement and implementation error, can be obtained from these diagrams. An optimal F that is unbiased in the sense that the probability of it being too high or too low is equal (ie. 50%) can be obtained from the median of the distribution in panel d (see values in Table C1). Taking into account the weight of landings the value balanced across all outcomes is obtained as the F giving maximum mean landings. For both plaice and sole these two estimates are fairly similar with differences in value of around $F=0.04$. For full management strategy evaluations uncertainty in measurements and implementation need to be included. Such errors result exploitation being away from the target value and change the the optimal point. For plaice the differences will probably be small as the mean landings against F is fairly flat around the optimum point (Figure C5c). As the maximum landing F is well below the F that gives 5% probability of $SSB < B_{lim}$ (Figure C5d) errors have little influence on risks of $SSB < B_{lim}$. For sole the mean catch/landings curve is more steeply domed (Figure C4c), and the probability of being below B_{lim} rises quickly if F is increased due to measurement or implementation errors because the F for 5% probability of $SSB < B_{lim}$ is close to the F for maximum exploitation (Figure C4d). In this case a lower more precautionary F may be required.

Table C2 Estimates of F for maximum landings under equilibrium exploitation.

	Distribution of F giving maximum landings	Average Landings
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	Mode	Median	Mean	Maximum Mean
NS sole	0.40	0.39	0.43	0.35
NS plaice	0.20	0.22	0.28	0.25

4. Conclusions

The approach described here provides a way to include uncertainty in the form of the functional relationship between recruitment and SSB. It gives a baseline for management simulations, but does not take into account the errors that need to be included in MSE or social or economic targets for fisheries.

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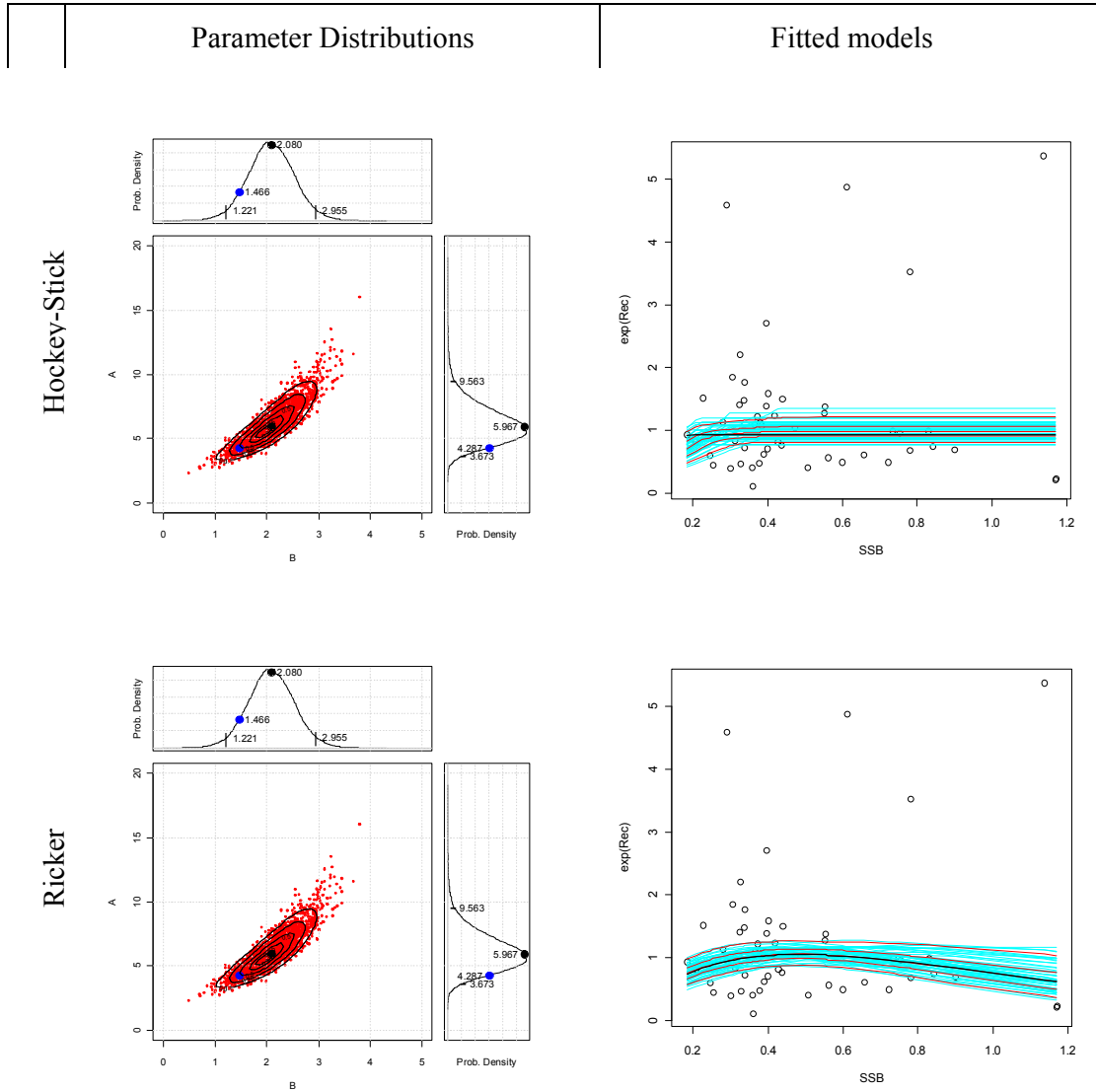


Figure C1 Stock/Recruit models for North Sea sole.

Parameter Distributions; joint probability distributions of coefficients A and B (values: red dots, contours of distribution: black lines, medians: black dots and maximum likelihood values: blue dots)

Fitted Models based on SSB/R values 1957-2007 (circles) showing 50 of the models picked at random models: cyan lines, maximum likelihood model: black line and the 5,25,50,75 and 95% quantiles of mean R on SSB from the distribution of models.

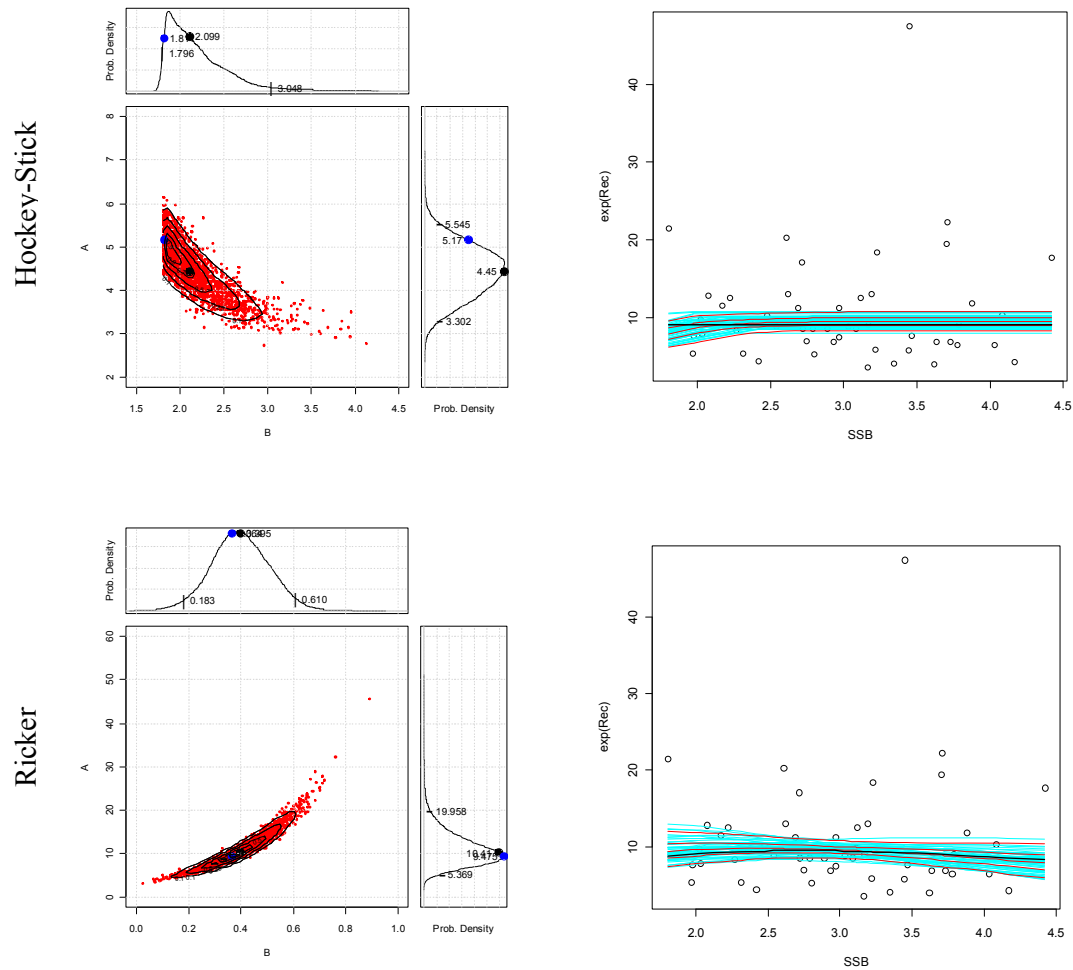


Figure C2 Stock/Recruit models for North Sea plaice.

Parameter Distributions; joint probability distributions of coefficients A and B (values: red dots, contours of distribution: black lines, medians: black dots and maximum likelihood values: blue dots)

Fitted Models based on SSB/R values 1957-2007 (circles) showing 50 of the models picked at random models: cyan lines, maximum likelihood model: black line and the 5,25,50,75 and 95% quantiles of mean R on SSB from the distribution of models.

- a) Simulated and observed recruits / SSB b) Cumulative pdf

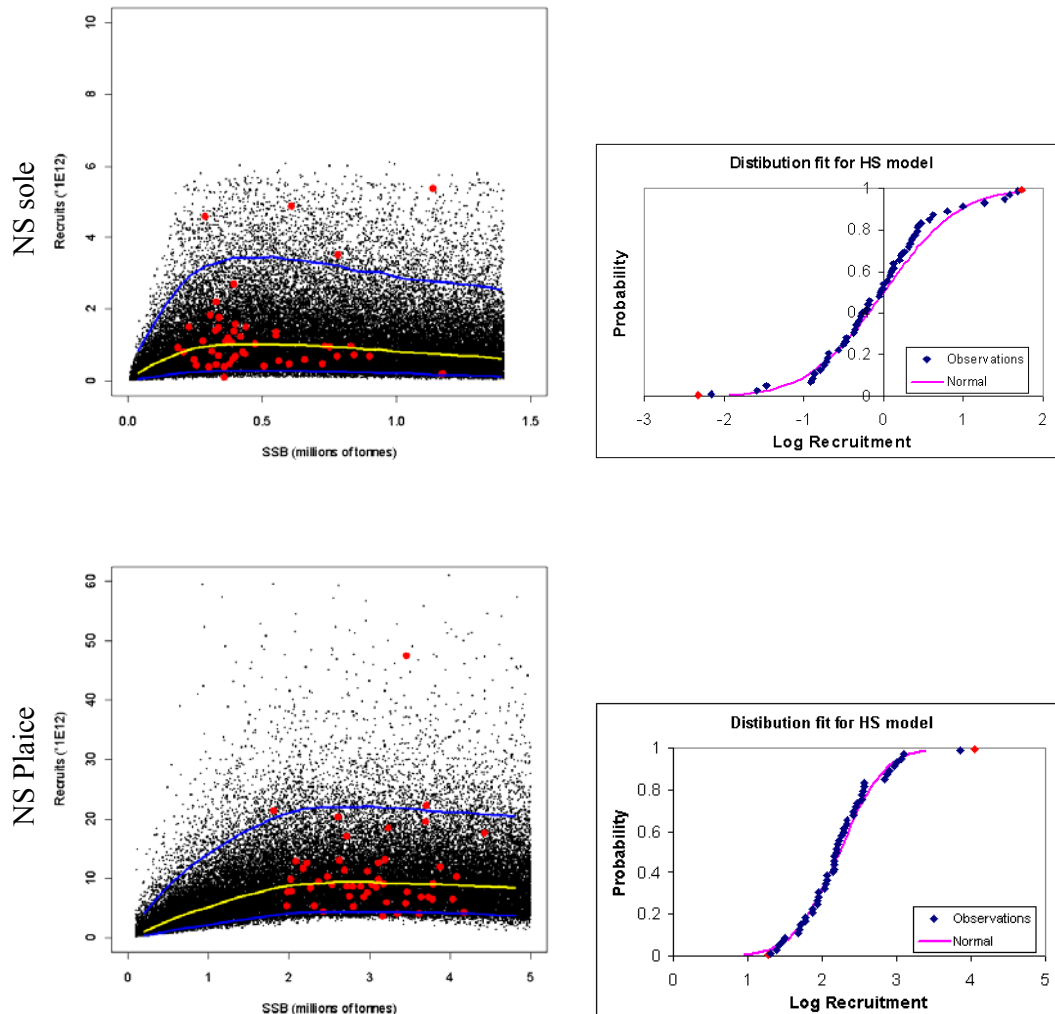


Figure C3 Comparison between observed and simulated recruitment for NS plaice and sole based on Bayesian models in Figures C1 and C2 and the model probabilities in Table C1.

- R against SSB, simulated values (black), observed (red) 5 and 95% (blue line) median (yellow line)
- Comparison of cumulative probability distributions of observed (blue) simulated (pink) and truncation limits (red)

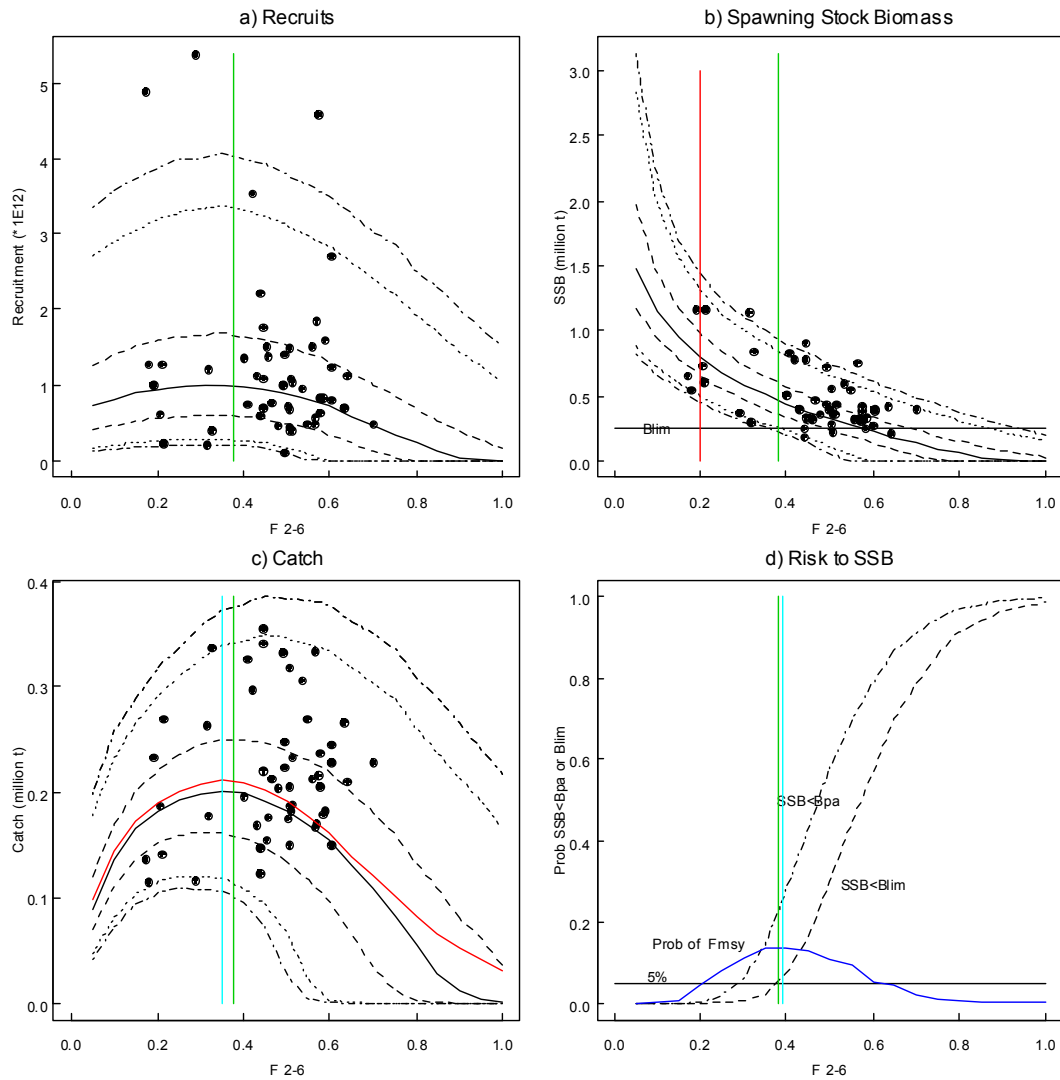


Figure C4 Equilibrium exploitation of NS sole against target F from $F=0.05$ to 1.0 .

Quantiles (0.025, 0.5, 0.25, 0.5, 0.75, 0.95, 0.975) of simulated a) Recruits, b) SSB and c) Catch/Landings: black lines. Historic Recruits, SSB and Catch/Landings black dots. c) mean catch/landings: red line. d) probability of SSB below B_{lim} and B_{pa} : black lines and 5% probability of SSB below B_{lim} green line in all panels. d) distribution of F for maximum catch/landings blue line. F for maximum catch/landings: cyan line, based on 50% point on distribution of F panel (d) and maximum mean catch/landings panel (c). The red line in panel b shows the current management plan target F .

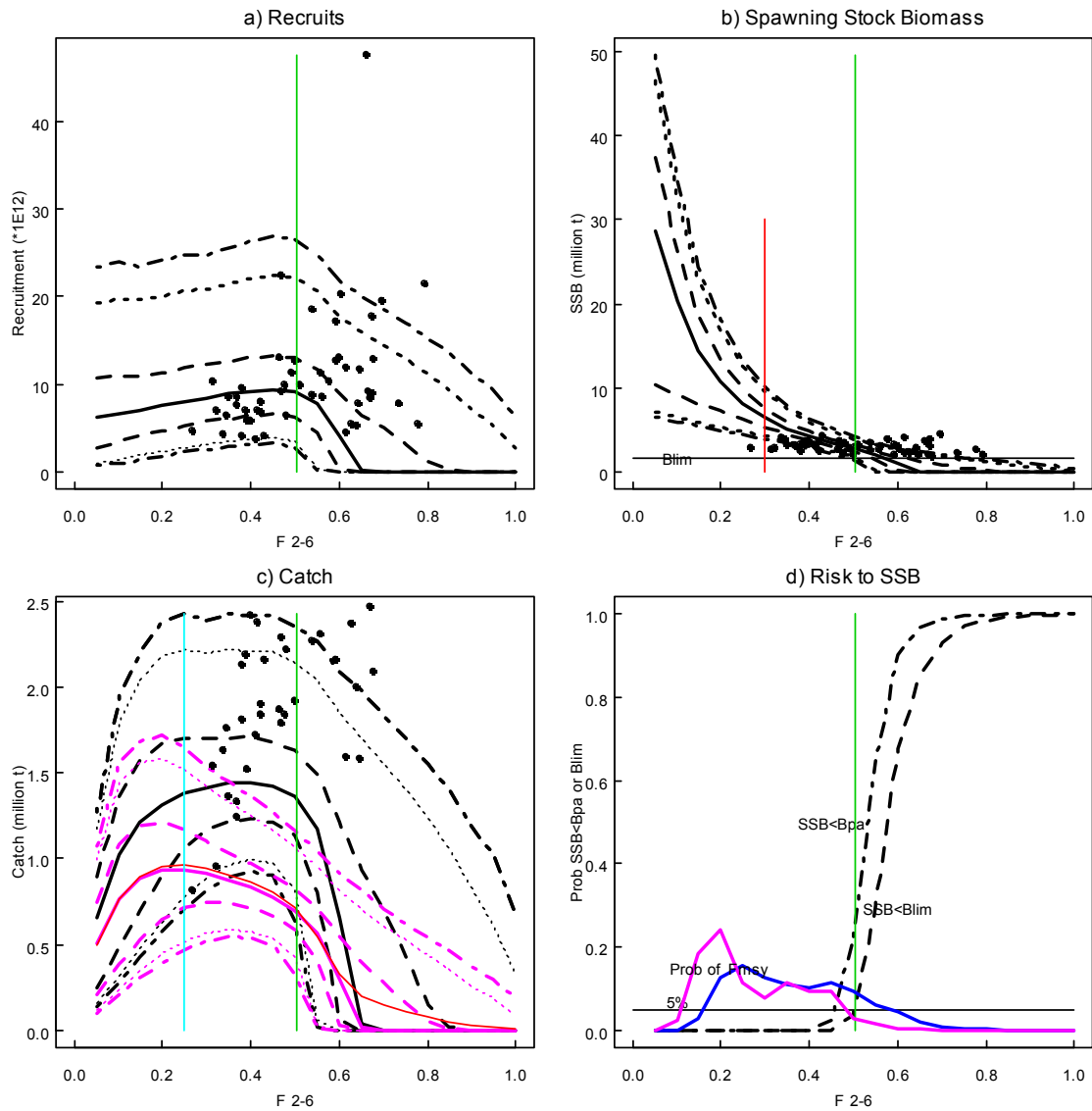


Figure C5 Equilibrium exploitation of NS plaice against target F from $F=0.05$ to 1.0 . Quantiles (0.025, 0.5, 0.25, 0.5, 0.75, 0.95, 0.975) of simulated a) Recruits, b) SSB and c) Catch: black lines and Landings pink lines. Historic Recruits, SSB and Catch: black dots. c) mean landings: red line. d) probability of SSB below Blim and Bpa: black lines and 5% probability of SSB below Blim green line in all panels. d) distribution of F for maximum catch, blue line, and maximum landings, pink line. F for maximum Landings: cyan line, based on 50% point on the distribution of F panel (d) and maximum mean Landings panel (c). The red line in panel b shows the current management plan target F .

ANNEX D: DETAILED DESCRIPTION OF THE FISHRENT MODEL

INTRODUCTION

The model (called FISHRENT) simulates values of biological and economic variables and shows explicitly the consequences of different policy decisions. The model was developed for the EU-project resource rent and has been adapted in this project for the evaluation of the North Sea management plan. In this annex a detailed description of the different modules of the model are given. More information about the FISHRENT model and an extensive application can be found in Saltz et al 2010.

The FISHRENT model was developed on the basis of earlier experiences of the team in bio-economic modeling, inter alia EIAA, BEMMFISH, TEMAS, AHF and others which were evaluated within the project 'Survey of existing bio-economic models' (Prellezo et.al. 2009). However, none of these models was appropriate to estimate resource rents under different conditions and management regimes, as required in the present project.

On the basis of the review of models and the objective of the project, it became evident that a new model had to be constructed which would meet the following requirements:

- Integrate simulation (application of different management strategies) and optimization (to determine optimum value of resource rent and other variables).
- Integrate output- and input-driven approaches, so that one model could be consistently applied to different situations in the EU
- Accommodate multi-species / multi-fleet fisheries, with flexible number of species and segments.
- Close link to available economic and biological data, to allow empirical applications.
- Balanced composition between various components: biology-economics-policy.
- Dynamic behaviour over a long period, including stock-growth, investment and effort functions, to allow simulation of adjustment paths to an optimum.
- Flexibility for applications of various types of relations (e.g. different stock-growth functions, approaches to payment for access, etc.).

In Saltz et al. 2010 a description is given of the FISHRENT model. This description is followed here and adjusted where changes were made compared to the original FISHRENT model. The original FISHRENT model was built in excel. For this project the model was translated to GAMS as the use of GAMS increases the flexibility of the model in terms of adding segments, species and changing the production

The FISHRENT is a full feed-back model, containing independent procedures for the development of the stock (stock-growth function), production and effort (production and investment function). Consequently the model can shift according to the most restrictive constraint, be it the total available effort of each fleet segment or the TAC/quotas of specific species. This approach allows to simulate the economic performance of individual fleet segments independently of each other over a long period of time.

FISHRENT modules

The FISHRENT model consists of 6 different modules. The biological module contains the stock-growth function. The economic module contains the economic performance of the fleets. The core section of the model is the interface which contains the bio-economic production functions for each combination of segment and species. This module reflects the interaction between the fishing fleet and the fish stocks. The price module contains fish price elasticities and the possibility to adapt the price fuel. The behaviour module determines the (dis)investment behaviour of the fleet, according to the realized economic performance. The policy module contains six policy options based on different approaches to management by TACs and effort including an option of open access fishery.

The relations within each module are in general terms described below. The mathematical description, including the required constraints and decision rules, is presented in the following section.

Model definition

The MP sheet contains all input and the year 1 as the baseline for the MYM sheet. The following sections present the mathematical formulation and discuss their meaning.

All variables are composed as follows:

Name_{xy}, x = segment index, y = species index;

when index = a means, sum of *all* species and/or segments

Parameters are composed as:

Name_{xyz}, x = segment index, y = species index and

z = sequential number of the parameter in a relation;

This notation and the names of the variables and parameters are as in the model. Parameters are written in italics, variables in normal. In most equation, only variables of the same year are related, so that time denomination is not required. When referring to preceding year, time denomination (t-1) is stated.

The model makes a distinction between ‘target’ and ‘non-target’ species. Target species are species included explicitly in the model with their biological functions.. Non-target species are all other species caught / landed by the segment. Non-target species must be included to obtain the total revenues of the segment.

The model distinguishes segments and 'other segment'. Segments are those explicitly included in the model with their economic functions. Other segments are segments catching target species.

The other segments must be included to obtain the correct fishing mortality of each target species.

Catches of 'other species' by 'other segments' are not included in the model.

Biological module

The biological module consists of a growth function and a biomass function.

Growth function

The biological module simulates the growth for each species using 3rd degree polynomial stock-growth function.

$$(1) \text{Rec-ay} = \text{Rec-ay0} + \text{Rec-ay1} * \text{CB-a1}^{\text{Expo-ay1}} - \text{Rec-ay2} * \text{CB-a1}^{\text{Expo-ay2}} + \text{Rec-ay3} * \text{CB-a1}^{\text{Expo-ay3}}$$

Where: CB = catchable biomass

Rec = parameters

Expo = exponents / parameters

The advantage of the 3rd degree polynomial is that it is easy to estimate. It is well known that stock-growth and stock-recruitment functions are statistically weak. The function selected in the model is just one of many possibilities and may be replaced by functions like Ricker or hockey-stick. This would be an interesting enhancement of the model.

Biomass function

The biomass function contains the following elements:

- Biomass of the preceding year;
- Recruitment;
- Catch of the individual segments, upgraded for discards of undersized fish (not part of TAC).
- Upgrade of the catch of segments 1-8 for catch by other segments, expressed as (1- sum of TAC shares);
- Lower limit CB=1, not allowing the species to be fished out completely. In this case CB is set at a low value of 0.000001 as otherwise the catch may exceed the biomass and in this way this anomaly is reduced to a very low value. The problem that Catch may exceed CB could be resolved by introducing a CBproxy,

which would first check whether $Catch < CB_{proxy}$. However, this would further complicate the model and the numerical results would not be significantly improved.

$$(2) CB_{ay} = IF \{ (CB_{ay_{t-1}} + Rec_{ay_{t-1}} - [\sum_x Catch_{xy_{t-1}} * (1 + Disc_{xy0})]) / (\sum_x TACsh_{xy0}) \} < 1, \\ 0.000001, \{ (CB_{ay_{t-1}} + Rec_{ay_{t-1}} - [\sum_x Catch_{xy_{t-1}} * (1 + Disc_{xy0})]) / (\sum_x TACsh_{xy0}) \}$$

Where CB_{t-1} = catchable biomass in year t-1

Rec_{t-1} = growth in year t-1

$Catch$ = catch in year t-1

$Disc$ = discards of undersized fish

TAC = TAC share of the segment

Specific effort has been put into optimizing the results of the stock-growth function with the projection of the stock calculated by biologists.

Economic module

Revenues

Gross revenue is estimated for each fleet segment taking the landings net of discards and multiplied with constant fish prices. Prices differ for the species but are constant for all segments. Revenues from target species are upgraded by revenues from other species, either by a lump sum or a percentage. Specific price

differential of the segment from the average is also included.

$$(3) Rev_{xa} = (\sum_y Land_{xy} * FishPr_{ay} * PrSeg_{xy0}) * (1 + OtSpR_{xa0}) + OtSpF_{xa0} * Eff_{xa}$$

Where $Land$ = landings

$FishPr$ = fish price

$PrSeg$ = price differential for the segment from the average price

Eff = effort

$OtSpR$ = revenues from non-target species as a percentage of target species

$OtSpF$ = revenues from non-target species per unit of effort

Fuel costs

The fuel costs depend on fuel use per unit of fishing effort, effort and fuel price. Fuel price may be differentiated between segments.

$$(4) \text{FuC-}xa = \text{FuC_}xa0 * \text{Eff-}xa * \text{FuelPr_}1a0$$

Where FuC = fuel use per unit of fishing effort

Eff = effort

FuelPr = fuel price

Crew costs

Crew costs are calculated as a share of the gross revenues after deduction of fuel costs.

$$(5) \text{CrC-}xa = (\text{Rev-}xa - \text{FuC-}xa) * \text{CrC_}xa0$$

Where Rev = revenues

FuC = fuel costs

$\text{CrC_}xa0$ = crew share

Variable costs

In contrast to the original FISHRENT model the other variable costs, being e.g. costs of landings, auction and harbour fees, depend on fishing effort instead of revenue.

$$(6) \text{VaC-}xa = \text{Eff-}xa * \text{VaC_}xa0$$

Where Eff = effort

$\text{VaC_}xa0$ = variable costs per unit of effort

Fixed costs

The fixed costs, also named vessel costs or semi-fixed costs are administration, insurance, maintenance etc. It is assumed that these costs are dependent on the value of the segment. The value of the segment is separated in a unit price per vessel and the number of vessels. In this way fixed costs will change with the changing size of the fleet in the segment.

$$(7) \text{ FxC-}x_a = \text{FxC_}x_{a0} * \text{Fle-}x_a * \text{InvPrice_}x_a$$

Where Fle = number of vessels

$\text{FxC_}x_{a0}$ = fixed costs per vessel

$\text{InvPrice_}x_a$ = percentage change in the vessel price

The unit price ($\text{InvPrice-}x_a$) is determined taking the total fixed costs for a segment in the base year divided by the number of vessels.

Capital costs

Capital costs are calculated in the same way as fixed costs,

$$(8) \text{ CaC-}x_a = \text{CaC_}x_{a0} * \text{Fle-}x_a * \text{InvPrice_}x_a$$

Where Fle = number of vessels

$\text{CaC_}x_{a0}$ = capital costs per vessel

$\text{InvPrice_}x_a$ = percentage change in the vessel price

Gross cash flow

The gross cash flow is the difference between revenues and all operational costs.

$$(9) \text{ GCF-}x_a = \text{Rev-}x_a - \text{FuC-}x_a - \text{CrC-}x_a - \text{VaC-}x_a - \text{FxC-}x_a$$

Where Rev = revenues

FuC = fuel costs

CrC = crew costs

VaC = variable costs

FxC = fixed costs

Profit

Profit is calculated as revenue minus all cost.

$$(10) \text{Prf-}x_a = \text{GCF-}x_a - \text{CaC-}x_a$$

Where GCF = gross cash flow

CaC = capital costs

Break-even revenues

The break-even revenue shows the gross revenue with given capital costs that yields a zero profit at. It is a useful indicator showing how far away a fishery is from making profit and thereby also provides information about overcapacity in term of excess capital costs. Ratio of break-even revenues to realized revenues determines the level of investments in the following period.

$$(13) \text{BER-}x_a = (\text{CrC-}x_a + \text{FxC-}x_a + \text{CaC-}x_a) / [(1 - \text{FuC-}x_a/\text{Rev-}x_a - \text{VaC-}x_a/\text{Rev-}x_a)]$$

Where CrC = crew costs

FxC = fixed costs

CaC = capital costs

FuC = fuel costs

Rev = revenues

VaC = variable costs

Interface Module

The interface module provides the link between the biological and the economic module. The core equation of the model is the Cobb-Douglas production function. The catch (excl. undersized discards) is a function of effort, stock abundance and technological progress. In contrast to the original FISHRENT model we have included the possibility of 2 types of effort: effort targeting sole and effort targeting plaice. Any vessel targeting sole is expected to catch plaice as a bycatch. Any vessel targeting plaice is expected to only catch plaice.

Catch function sole

$$(15) \text{ Catch-}xs = \text{Catch-}xs0 * \text{Eff-}xs^{\text{Catch-}xs1} * \text{CB-}xs^{\text{Catch-}xs2} * (1 + \text{Catch-}xs3)$$

Catch function plaice

$$(15) \text{ Catch-}xp = \text{Catch-}xp0 * \text{Eff-}xp^{\text{Catch-}xp1} * \text{Catch-}xs^{\text{Catch-}xp3} * \text{CB-}xp^{\text{Catch-}xp2} * (1 + \text{Catch-}xp3)$$

Where Eff-s =Effort sole

Eff-p =Effort plaice

Catch-s= catch sole

CB = Catchable biomass

Catch_xy3 = Rate of technological progress

Catch_xy0, *Catch_xy1*, *Catch_xy2* = estimated parameters

$$\text{Catch_}xs1 + \text{Catch_}xs2 = 1$$

$$\text{Catch_}xp1 + \text{Catch_}xp2 + \text{Catch_}xp3 = 1$$

$$\text{Eff} = \text{Eff-s} + \text{Eff-p}$$

The total catch of a species must also account for catch by ‘other segments’, which has been accounted for in the biomass function (2). The parameters of the function are estimated based on theory and few empirical studies. The technological progress is hardly above 1.5% per year (Frost et al, 2009). For trawlers that are less impacted by stock abundance than by vessels technology the exponent for effort is between 0.6-0.9 while the exponent for the stock is between 0.1-0.4. For gillnet the opposite is to be expected. For pelagic and demersal species with schooling behavior the exponent for the stock is low while it is higher for demersal species. Setting these parameters makes it possible to estimate the *Catch-xy0* parameter.

The importance of the exponents is quite significant and the possibilities of switching for one target species to another should be estimated further.

Over-quota discards

The landings are derived from the catches after subtraction of over-quota catches, which must be discarded.

$$(16) \text{ Disc-xy} = \text{IF}(\text{Catch-xy} > \text{LandT-xy}, \text{Disc_xyI} * (\text{Catch-xy} - \text{LandT-xy}), 0)$$

Where Catch = catch

LandT = target catch, based on segment share in TAC (see policy module)

Disc = share of over-quota catch which is discarded

Behaviour Module

The behaviour module determines the (dis)investment and changes in effort level (days-at-sea per vessel).

Investment function

Theoretically the investments are determined by expectations of future profit, but there is no empirical data, which could be used to support such theorem in the model. Instead, perceived profitability in the preceding year, expressed as ratio between break-even revenues minus realized revenues divided by realized revenues is used to determine in the (dis)investments in each year. When break-even revenues exceed realized revenues then the fleet will expand and vice versa.

This leads in some years to quite substantial changes in the number of vessels in a fleet segment, which can be justified as vessels from other segments may enter the given fishery. At the same time, it was recognized that the inertia of the system does not allow such full flexibility. Consequently, parameters have been introduced as limits to maximum annual (dis)investments. As different parameters have been applied to investments and disinvestments, an asymmetric investment behaviour can be simulated.

Furthermore, it has been assumed that the active fleet will first achieve a certain minimum number of days-at-sea per vessel before the number of vessels will be expanded. This assumption was introduced to avoid continuous growth of the fleet, while at same time the number of days-at-sea per vessel would be proportionately falling.

$$(17) \text{ Inv-xa} = \text{IF}(\text{DASope-xa} < \text{InvDays_xa3} * \text{DASmax-xa}, -(\text{InvLimd_xa2} * \text{FLE-xa}), \\ \text{IF}(\text{BER-xa} < 0, -(\text{InvLimd_xa2} * \text{FLE-xa}), \\ \text{IF}(\text{PrfShare_xa0} * (\text{REV-xa} - \text{BER-xa})_{t-1} / \text{REV-xa}_{t-1} > \text{InvLimu_xa1}, \\ \text{InvLimu_xa1} * \text{FLE-xa},$$

$$\begin{aligned}
& \text{IF}(\text{PrfShare_xa0} * (\text{REV-xa} - \text{BER-xa})_{t-1} / \text{REV-xa}_{t-1} < -\text{InvLimd_xa2}, \\
& \quad \text{InvLimd_xa2} * -\text{FLE-xa}, \\
& \quad \text{PrfShare_xa0} * (\text{REV-xa} - \text{BER-xa})_{t-1} / \text{REV-xa}_{t-1} * \text{FLE-xa})))
\end{aligned}$$

Where Rev = revenues

BER = break-even revenues

Fle = fleet, number of vessels

DASope = operational (actual) number of days-at-sea per vessel

DASmax = maximum number of days-at-sea per vessel

PrfShare_xa0 = share of profit dedicated to investments,

InvLimu_xa1 = upper limit for investments, as a relative change of the fleet

InvLimd_xa2 = lower limit for investments, as a relative change of the fleet

InvDays_xa3 = minimum level of capacity utilization, under which no
investments take place

Fleet (number of vessels)

Number of vessels in a segment is equal to the fleet of preceding year plus the (dis)investments in that year.

$$(19) \text{Fle-xa} = \text{Fle-xa}_{t-1} + \text{Inv-xa}_{t-1}$$

Where Fle = fleet

Inv = (dis)investments

The number of vessels is constant if the investment function is turned off e.g. by setting the profit investment share, PrfShare-xa0, at zero. Changes in the number of vessels affect the number of days-at sea, fixed and capital costs and ultimately the profit.

Price module

Fish prices

Fish prices are based on the prices of the baseline year, possibly adapted by a price elasticity. However, this is only relevant if the fishery lands a significant share of the total supply of a species.

$$(20) \text{FishPr}_{ay} = \text{FishPr}_{ay0} * (\text{Land}_{a1} / \text{Land}_{a1_{t-1}})^{(-PrEl_{a11})}$$

Where FishPr = fish price

Where Land = landings

PrEl = price elasticity

Fuel price

The fuel price level can be adjusted by an annual percentage change (*FuelPr*-*xa0*), which can be also differentiated between fleet segments.

$$(21) \text{FuelPr}_{-xa} = \text{FuelPr}_{-xa_{t-1}} * (1 + \text{FuelPr}_{-xa0})$$

Where *FuelPr*-*la0* = is annual percentage change of fuel price

Policy module

Policy choice

The FISHRENT model allows for several policy option to be taken. The fisheries management pursues the achievement of long term sustainable exploitation of fish stocks at MSY level. There are in principle two approaches: output (TAC) driven approach and effort driven approach. Although in some fisheries constraints in both areas exist, one of them is always most binding.

However, in a multi-species multi-fleet situation, it is fundamentally impossible to achieve the MSY level for all species concurrently. This gives rise to two situations:

- One species is fished at MSY level, while other species are overfished. Policy focusing on this species will be least restrictive, using the TAC or effort related to that species as benchmark for the overall activity of the fleet.
- One species is fished at MSY level, while other species remain underutilized. Policy focusing on this species will be most restrictive, using the TAC or effort related to that species as benchmark for the overall activity of the fleet.

These two options have been included in the model. A third option, which would take some 'average' value as a starting point has not been modeled, as it is not clear how such 'average' should be determined and because the two 'extreme' options provide information about the 'limits of the system' within which all other options fall.

The model requires to determine a unique and consistent composition of three elements:

- catches, which affect biomass,
- landings, which determine revenues, and
- effort, which determines part of the costs.

This is achieved in the policy module in principle as follows:

1. The MSY level of biomass and growth (sustainable harvest) of each species is calculated from the 2nd degree polynomial stock-growth function, by setting the first derivative equal to zero.
2. The resulting ratio $(\text{Catch}/\text{Biomass})_{\text{msy}}$ is interpreted as F_{msy} .
3. Actual fishing mortality (F) realized in each year is compared to F_{msy} and the ratio (F_{msy}/F) determines the biologic advice - either effort or TAC is adjusted by that ratio. Evidently, the ratios are different for each species, which creates the need to select from the most or the least restrictive approach.
4. It is than a policy choice to determine whether output or input driven policy should be implemented and whether the most or the least restrictive approach should be followed.

In this evaluation it is assumed that the TAC are set based on the sustainable catch and the vessels allocated their effort in such a way that they can catch the available TAC. It maybe the outcome of the model that the quota of one species is limiting and due to the bycatch of this species when targeting other species the available effort can not be fully employed.

Sustainable catch and selected TAC

The TACs in this model are calculated based on the sustainable catch. Sustainable catch is calculated as the growth of the biomass, including natural mortality and adapted to the

ratio fishing mortality divided by total mortality. In some fisheries it has been agreed that the TACs would change at most by X% from one year to another. Therefore, this constraint has been also incorporated.

The constrained can be lifted by setting TAC-ay0=0.

$$\begin{aligned}
 (22) \text{TAC-ay} = & \text{IF}(\text{CB-ay} * (1 - \text{EXP}(-(F_{\text{target_ay0}} + M_{\text{ay0}}))) * F_{\text{target_ay0}} / (F_{\text{target_ay0}} + M_{\text{ay0}}) < \\
 & (1 - \text{TAC_ay0}) * \text{TAC-ay}_{t-1}, (1 - \text{TAC_ay0}) * \text{TAC-ay}_{t-1}, \\
 & \text{IF}(\text{CB-ay} * (1 - \text{EXP}(-(F_{\text{target_ay0}} + M_{\text{ay0}}))) * F_{\text{target_ay0}} / (F_{\text{target_ay0}} + M_{\text{ay0}}) > \\
 & (1 + \text{TAC_ay0}) * \text{TAC-ay}_{t-1}, (1 + \text{TAC_ay0}) * \text{TAC-ay}_{t-1}, \\
 & \text{CB-ay} * (1 - \text{EXP}(-(F_{\text{target_ay0}} + M_{\text{ay0}}))) * F_{\text{target_ay0}} / (F_{\text{target_ay0}} + M_{\text{ay0}}))
 \end{aligned}$$

Where CB-ay = catchable biomass

Ftarget-ay0 = target (msy) fishing mortality

M-ay0 = natural fishing mortality

TAC-ay0 = maximum change of TAC from one year to another

TAC-ay_{t-1} = TAC preceding year

Landings

Landings of a segment are catches minus over-quota discards.

$$(24) \text{Land-xy} = \text{Catch-xy} - \text{Disc-xy}$$

Where Catch = catch

Disc = over-quota discards

The TAC function does pose some restrictions on the model. Based on the initialization of the parameters the initial calculated TAC can be quite restrictive. Some further study in the estimation of the TAC would be beneficial to the model.

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ANNEX E DECLARATIONS OF EXPERTS

Declarations of invited experts are published on the STECF web site on <https://stecf.jrc.ec.europa.eu/home> together with the final report.

European Commission

EUR 24629 EN – Joint Research Centre – Institute for the Protection and Security of the Citizen

Title: Scientific, Technical and Economic Committee for Fisheries. Report on the meeting on Multi-annual Plan Evaluations Impact Assessments: b) Impact assessment of North Sea plaice and sole multi-annual plan.

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Abstract

This report is one five parts of the report of SG MOS 10-06, the STECF sub group on management objectives and strategies dealing with historic Evaluations of and future Impact Assessments of multi-annual plans for fisheries. In total five separate reports are prepared by STECF-SGMOS 10-06 WGs, the first, scoping meeting report STECF-SGMOS 10-06a.contained preparatory work, the other four report the individual assessments:-

STECF-SGMOS 10-06b Report of the Impact Assessments for North Sea plaice and sole multiannual management.

STECF-SGMOS 10-06c Report of the Impact Assessments for Western Channel sole multiannual management.

STECF-SGMOS 10-06d. Report of the Evaluations of Southern hake and Nephrops Multi-annual plan

STECF-SG MOS 10-06e. Report of the Evaluations of Baltic cod Multi-annual plan

This report describes an Impact Assessment of the performance of the multi-annual plan for fisheries of plaice and sole in the North Sea.

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